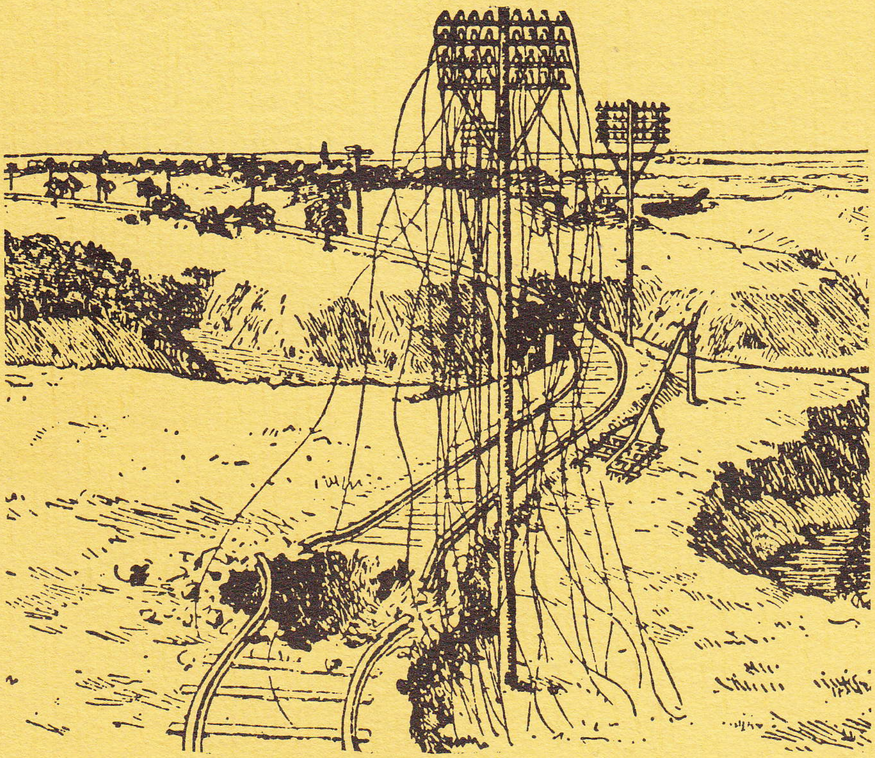
American ENGINEER EXPLOSIVES



in World War One

American

ENGINEER EXPLOSIVES

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the COMBAT BOOKSHELF

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engineer explosives

A military explosive for demolitions should be—

1. Not too sensitive to shock or friction.
2. Of a high velocity of detonation.
3. Of high power.
4. Of high density.
5. Stable in character.
6. Not too difficult of detonation.
7. Unaffected by changes of temperature and moisture.
8. Convenient in form for packing and loading.
9. Obtainable in large quantities in the United States.

The authorized explosive, Triton, meets the above standard more nearly than any other explosive known. It must be recognized, however, that there are many other explosives made and used in this country, of almost equal value for general military uses and of superior value for some special purposes. The engineer reconnaissance of any locality must show the commercial explosives at hand, and the officer executing demolitions must use these explosives whenever time permits their collection or when the authorized explosive is lacking. The use of other explosives in this manner also saves the valuable triton for use where the maximum speed and certainty of execution is demanded. Consequently, a knowledge must be possessed of the nature and properties of the commercial explosives commonly used in the United States.

Triton—Nature.—Triton (Trinitrotoluene) is produced in the form of crystals of a light yellow color. It melts at 80° C. These crystals, compressed to a density of 1.48, are issued in two forms, **the triton block,** weighing one-half pound, and **the triton stick,** weighing 0.4 of a pound. Each form of triton is issued copper-plated, and each has a cylindrical hole to receive the detonating cap (formed in the block or stick). This cap hole is closed with a cork

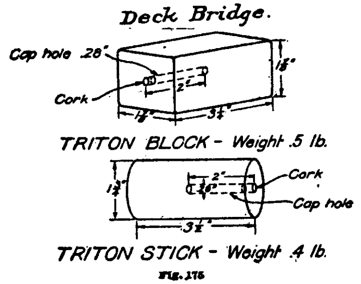


Fig. 175

Fig. 177

Fig. 178

Fig. 176

as a precaution against moisture. The purpose of copperplating the blocks is to protect the triton from moisture and also from abrasion. Moisture very much reduces the strength of triton. Triton is very insensitive and can be cut with a knife or other steel implement. It does not form explosive salts with metallic oxides, and burns in small quantities with a very smoky flame without exploding. In large quantities there is danger of explosion if heat is suddenly applied. If melted and cast, it has a density of 1.6. In all forms triton is insensitive and requires a powerful detonating agent. The loose crystals are the most sensitive form, and the cast triton the least sensitive. It is noteworthy that a boosting charge of loose crystalline triton will detonate compressed triton **(as issued)**, and compressed triton will detonate cast triton. Poisonous gases are produced on detonation but are so rapidly dissipated as to be harmless in open air. Triton is, however, unsafe for use underground or where explosive gases are present. If detonated underground, carbon monoxide is formed and unless this poisonous gas is removed by ventilation, the men who enter an underground work in which triton has been detonated, are in grave danger. Its use in underground workings is inadvisable, and the precautions required by its peculiar properties must be taken.

Triton is shipped in boxes containing about 50 pounds, marked **"High explosive; dangerous."** These boxes are to be opened with care, pulling the nails with very little hammering or other vigorous handling of the boxes.

The copperplating has little, if any, effect upon the sensitiveness or power of the triton. If triton is furnished uncopperplated it must be scrupulously protected from moisture. Triton can be surely detonated only with the tetryl caps or detonating cord. However, one box of triton will detonate triton in unopened boxes placed against the primed box.

Value.—Triton is of high power, safe to handle, and can be surely detonated by the prescribed detonators. It is produced in large quantities in the United States.

Triton is used abroad in the French Army to some extent under the name **Tolite,** and in the German Army under the name **Sprengmunition 02.**

208. **Picrates.**—Picric acid is formed in crystals of a light-yellow color, melts at 122° C., and burns slowly with a light yellow flame. In contact with metals it forms highly sensitive and dangerous metallic picrates. It is shipped in wooden boxes lined with paper. It is of slightly higher power than triton. If heated suddenly it will explode. Moisture reduces the sensitiveness and power of picric acid.

Value.—Very similar to triton, but not as stable, and also dangerous if in contact with metals.

Picric acid is used abroad by the French in the form of Melinite, and in the German Army under the name of Sprengmunition 88.

209. **Gunpowder—Nature.**—This explosive, formed of a mixture of saltpeter, sulphur, and charcoal, is still of some military value for demolitions. It can be ignited by the mere application of a flame, as from a burning fuse or miner's squib. Water destroys the power of gunpowder. **Thorough tamping** is an absolute necessity for successful use of gunpowder in mines or demolitions. The power of gunpowder when well tamped is about one-third that of triton.

Value.—Gunpowder is still produced and used in considerable quantities in this country and is of considerable military use in land mines or other locations where thorough tamping is possible. The extensively used commercial English bobbinite is essentially a gunpowder.

210. **Nitroglycerin explosives—(a) Straight dynamites—Nature.**—These are sold in the United States as 15, 20, 25, 30, 35, 40, 45, 50, 55, and 60 per cent dynamites, according to the proportion of nitroglycerin contained. The other constituents are combustible material (wood pulp, flour, sulphur, etc.), sodium nitrate, and calcium or magnesium carbonate. Fifty per cent straight dynamite is equal in power to **triton** weight for weight. Dynamite is furnished in sticks, wrapped in paper, of about 0.5 of a pound each. The sticks are packed in wooden boxes of two sizes containing, respectively, 25 and 50 pounds. Forty per cent dynamite is the grade most frequently encountered. The higher grades are exceptional.

Direct contact with water brings about separation of the nitroglycerin, and this constitutes a source of danger when the explosive is used in wet places. Its liability to freeze is another source of danger. Very strong detonators are required to explode it when frozen, and though in this condition it is fairly insensitive to a blow, breaking or crushing are distinctly dangerous operations. Thawing must be conducted with great care in a specially constructed double boiler provided with a jacket for hot water (fig. 178). Should exudation of nitroglycerin take place during thawing, this will introduce an element of danger in ramming.

During storage it must be protected from dampness and from heat; even sunlight must be avoided.

Value.—Dynamites are of high power and are readily obtainable. They are sensitive to shock, deteriorate in storage, and freeze at about 40° F.

(b) **Low freezing dynamites—Nature.**—Similar to straight dynamites, except not frozen at temperatures above 35° F. Sold in the United States as 30, 35, 40, 45, 50, 55, and 60 per cent. These percentages represent the proportion of nitroglycerin plus nitrosubstitution compound. The other ingredients are as noted for straight dynamite. The exact freezing point of these dynamites can not be exactly stated. In practice they have seldom been known to freeze above 0° F., and in special tests have remained unfrozen at temperatures as low as minus 40° F.

Value.—Similar to straight dynamites, with added value due to low freezing properties.

(c) **Blasting gelatin—Nature.**—Blasting gelatin is composed of 90 to 93 per cent nitroglycerin and 7 to 10 per cent collodion cotton. It is furnished commercially in a jellylike mass, packed in metal-lined wooden boxes. It is less sensitive than straight dynamite, liable to freeze, and is one of the most powerful explosives known. It is not affected by moisture.

Value.—Blasting gelatin has been largely replaced by the gelatin dynamite, but is a reliable explosive of very high power, about 2.1 times as powerful as triton.

(d) **Gelatin dynamite—Nature.**—This explosive is formed from blasting gelatin by the use of an absorbent to solidify the gelatin and thus make it more convenient for use. It is sold in this country as 30, 35, 40, 50, 55, 60, and 70 per cent gelatin dynamite. The actual percentage of nitroglycerin in each of these dynamites is about **10 per cent less** than the nominal quantity given. The other ingredients are nitrocellulose, sodium nitrate, combustible material (sulphur, flour, wood pulp, etc.), and calcium carbonate. Gelatin dynamites are of about 10 per cent less power, weight for weight, than straight dynamite of the same nominal percentage. Sixty per cent gelatin dynamite is equal to triton in power, weight for weight. Freezing of gelatin dynamite is a fault as in all other nitroglycerin explosives. It is, however, unaffected by water and is the most useful of the commercial dynamites, especially adapted for use in tunnel driving.

Value.—Gelatin dynamite is comparatively stable, adapted to work under water, is of high power, and is used in great quantities in this country.

(e) **Ammonia dynamite—Nature.**—This dynamite is sold in five grades in this country—30, 35, 40, 50, and 60 per cent. The nitroglycerin plus the ammonium nitrate in each grade varies slightly from the percentage given except for the 30 per cent grade. For the 60 per cent grade the variation amounts to about plus 5 per cent. The other ingredients are sodium nitrate, calcium carbonate, and combustible material.

Ammonia dynamites, compared with other dynamites, have the disadvantage of taking up moisture very readily, because ammonium nitrate is deliquescent, and care should be observed when they are stored or used in wet places.

Value.—Ammonia dynamites are distinctly superior to other dynamites only for use underground in the presence of explosive gases. Their use and storage where exposed to moisture tends to destroy their power. They are used extensively in coal mining in the United States. The low freezing ammonia dynamites are of great importance at the present time. The high price of glycerin has led to the use of this class of dynamite wherever water is not encountered.

(f) **Explosives for use in coal mines or elsewhere in the presence of pit gases (commercially known as permissible explosives)—Nature.**—These explosives, forming a long list, are those whose length, detonation, and temperature of flame accompanying detonation will not ignite mixtures of pit gas and air. Even for those listed there is a **charge limit** above which detonation is unsafe. The ammonia dynamites are included in these explosives, as well as other dynamites of low nitroglycerin percentage. The ammonia nitrates and other explosives are also included in this class. It is notable that **gunpowder, triton, picric acid, blasting gelatin, gelatin dynamite, and guncotton** are **not** suitable for such use. The name "permissible explosive" has very little military significance.

Value.—The great extent of the use of this group of explosives makes them of military value.

Ammonium nitrate explosives.—This class of explosives, developed to some extent prior to the present war, has come to the fore as a general military explosive. Of the numerous varieties of this class the most common ones contain 70 to 95 per cent ammonium nitrate, with the addition of combustible material, such as resin, meal, or naphthalene. **Ammonal** is a special type of this class, formed by a mixture of ammonium nitrate, aluminum, and a small percentage of trinitrotoluol. All of these explosives are very deliquescent and insensitive to shock.

Value.—The economic conditions created by the present war have so raised the prices of glycerin and toluol that this class of explosives is coming rapidly into prominence. An ammonium nitrate explosive is being used as a bursting charge for projectiles by both groups of combatants in the present war. It is notable that the only point of inferiority of selected types of this group for military use is their sensitiveness to moisture.

211. **Chlorate explosives—Nature.**—This group of explosives, consisting of a mixture of a metallic chlorate (sodium or potassium) with a hydrocarbon oil, are in most forms sensitive to shock and dangerous in use and storage. Cheddites in which castor oil is used is the most common form, is not highly sensitive to shock or friction, but has the disadvantage of easily becoming hard, and is then not completely detonated.

Sprengel explosives are chlorate explosives rendered reasonably safe by adopting the device of Sprengel and issuing the chlorate separately from the combustible matter. The potassium chlorate is made up into porous cartridges, and a liquid combustible is used; the former is dipped into the latter just before use.

Rack-a-rock, which has been used very extensively in America, consists of cartridges of chlorate of potash, which are dipped just before use into a combustible oil. For this purpose nitrobenzene is used, or "dead oil," which consists chiefly of hydrocarbons from coal tar, or a mixture of the two. The chlorate cartridges are inclosed in small bags of cotton; before use these are placed in a wire basket suspended from a spring balance and dipped into a pail containing the liquid, until a quarter to a third of the weight of the chlorate has been taken up. The chlorate sometimes contains an addition of a few per cent of iron oxide.

The objection has been raised to Sprengel explosives of this sort that the impregnation is not uniform, and the results obtained are consequently unreliable.

Value.—These explosives of the Sprengel type are of some military value, but have serious disadvantages, as noted, and in addition require considerable time to impregnate the chlorate properly before use.

212. **Guncotton—Nature.**—This explosive, manufactured by the nitration of cotton waste, is either molded in small cylinders or further compressed for use in military demolitions into blocks or cylinders of a density of from 1.05 to 1.2. Guncotton must be kept moist and is then highly insensitive. It requires a priming charge of dry guncotton for detonation. It is about 1.2 times as powerful as triton, weight for weight.

Value.—Guncotton is of high power, easily obtainable, but the necessity of using a priming charge of dry guncotton and its low density are disadvantages. It is used abroad to some extent as a military explosive for demolitions.

213. **Smokeless powder—Nature.**—This explosive, used so commonly as a propellant for projectiles, is liable to deteriorate in storage, and in storage must be guarded from ignition. It is difficult to detonate and, as it has a low velocity of detonation, must be thoroughly tamped for successful use as a demolition agent. It has about 1.2 times the power of triton.

Value.—The large production of this powder in the United States may call for its use in emergencies. The same instructions given for **gunpowder** apply to smokeless powder. It can only be used effectively where thorough tamping is possible, as in land mines, etc.

214. **The formula** given hereafter for triton in each case gives the number of **one-half pound** triton blocks required. To obtain the **pounds** of the following explosives to do the same work, multiply **N (the number of one-half pound triton blocks)** by **L** as given.

Explosive.	L.
Picric acid	0.50
Gun powder (if well tamped)	1.80
Straight dynamites:	
15 per cent	.84
20 per cent	.78
25 per cent	.74
30 per cent	.68
35 per cent	.62
40 per cent	.58
45 per cent	.54
50 per cent	.50
55 per cent	.48
60 per cent	.45
Low-freezing dynamites (same as Straight dynamites).	
Blasting gelatin	.25
Gelatin dynamite:	
30 per cent	.74
35 per cent	.70
40 per cent	.66
50 per cent	.60
55 per cent	.56
60 per cent	.52
70 per cent	.48
Ammonia dynamites (same as gelatin dynamites).	
Cholrates:	
Rack-a-rock	.78
Guncotton	.41
Smokeless powder (if well tamped)	.43

215. **Precautions to be taken in the care and use of explosives.**—(1) **Triton** must be protected from direct artillery fire, as a burst of shell within a mass of triton will detonate it. Moisture must be kept away from triton. Ordinary shocks from usage or the use of steel tools on triton is without danger. In use **thorough tamping** is necessary to get full effect from triton as well as **all** other explosives. Only the **Tetryl cap** or **detonating cord** will surely detonate triton. A boosting charge of powdered triton around a powerful commercial cap will usually detonate triton.

(2) **Picric** acid must be protected as noted for triton and must also be kept from contact with metals.

(3) In using **nitroglycerine explosives** of all kinds—

(*a*) Don't store detonators with explosives. Detonators should be kept by themselves.

(*b*) Don't open packages of explosives in a storehouse.

(*c*) Don't open packages of explosives with a nail puller, pick, or chisel. Packages should be opened with a hardwood wedge and mallet, outside of the magazine and at a distance from it.

(*d*) Don't store explosives in a hot or damp place. All explosives spoil rapidly if so stored.

(*e*) Don't store explosives containing nitroglycerin so that the cartridges stand on end. The nitroglycerin is more likely to leak from the cartridges when they stand on end than it is when they lie on their sides.

(*f*) Don't use explosives that are frozen or partly frozen. The charge may not explode completely, and serious accidents may result. If the explosion is not complete, the full strength of the charge is not exerted, and larger quantities of harmful gases are given off.

(*g*) Don't thaw frozen explosives before an open fire, nor in a stove, nor over a lamp, nor near a boiler, nor near steam pipes, nor by placing cartridges in hot water. Use a commercial or improvised thawer.

(*h*) Don't put hot water or steam pipes in a magazine for thawing purposes. Where large quantities of explosives are used, a special thaw house should be built, large enough to hold the quantity of explosives needed for a day's work.

(*i*) Don't carry detonators and explosives in the same package. Detonators are extremely sensitive to heat, friction, or blows of any kind.

(*j*) Don't handle detonators or explosives near an open flame.

(*k*) Don't expose detonators or explosives to direct sunlight for any length of time. Such exposure may increase the danger in their use.

(*l*) Don't open a package of explosives until ready to use the explosive; then use it promptly.

(*m*) Don't handle explosives carelessly. They are all sensitive to blows, friction, and fire.

(*n*) Don't crimp a detonator (blasting cap) around a fuse with the teeth. Use a cap crimper, which is supplied for this purpose.

(*o*) Don't economize by using a short length of fuse. Such practice is liable to result in a shot going off too soon.

(*p*) Don't return to a charge for at least one-half hour after a misfire. Hangfires and misfires are likely to happen.

(*q*) Don't attempt to draw nor to dig out the charge in case of a misfire.

Gunpowder and smokeless powder must be protected from fire and moisture.

Guncotton must be kept moist. It is very insensitive and requires a primer of dry guncotton. Dry guncotton deteriorates in the Tropics.

216. **Destruction of explosives.**—Such operations must be carried out under the direct charge of an experienced officer.

Triton or picric acid can be destroyed by burning or detonating in small masses. To burn, use inflammable material piled around the explosive, and ignite at a distance with a fuse or miner's squib. Dynamite can also be destroyed by burning. The dynamite, after removing wrapper, is burned in a similar manner to that just described. Detonation may occur, and the dynamite should be burned in small masses. All persons must be kept away from it when burning.

Gunpowder is destroyed by submerging in water. If no body of water is at hand it may be burned in small masses.

Smokeless powder is destroyed by burning in numerous small charges. Each charge of powder is ignited with a time fuse.

217. **Detonation.**—The detonation of an explosive is almost always affected by the detonation of a more sensitive explosive, of which a small quantity is placed in juxtaposition with the first and fired by mechanical shock, fuses, or electrical devices. Ordinary percussion cap composition contains a mixture of mercury fulminate, potassium chlorate, and antimony sulphide, to which powdered glass may be added in order to obtain increased sensitiveness. The caps for detonators are of pure copper, cylindrical in shape, closed at one end, and charged with an intimate mixture of 85 per cent mercury fulminate and 15 per cent potassium chlorate. Detonators are made in 10 sizes, numbered consecutively, and contain, respectively, 0.3, 0.4, 0.54, 0.65, 0.8, 1.0, 1.5, 2.0, 2.5, or 3 grams of the detonating mixture.

218. While the detonation of triton can often be secured with other caps, particularly if a boosting charge of powdered triton is used, the tetryl cap is necessary in order to **insure detonation.** This cap is furnished in two types, the **tetryl electric cap** and the **tetryl blasting cap.** The substance "tetryl" is the detonating agent in each type. The word tetryl is an abbreviation of the unwieldy name of a **complex** hydrocarbon. The tetryl in each type is detonated by a small charge of mercury fulminate The fulminate is detonated as in ordinary blasting or electric caps, i. e., by heat or shock.

219. **Precautions in detonation.**—Caps must be handled with extreme care. They can be detonated either by shock or heat. They must be packed and handled so as to avoid shock. The insulation used to close the mouth of the electric cap must not be injured. Caps must be kept dry. Avoid bringing the cap into contact with the explosive until the last practicable moment before use. Caps must not be pinched when crimping over the fuse. Crimp as near the open end of the cap as is practicable. Crimp caps before inserting in explosive. Caps must not be stored with explosives.

220. **Fuse.**—For the ignition of the detonator or, in the case of blasting explosives of the black powder class for the direct ignition of the charge, a fuse of one sort or another is used (figs. 179 to 182). In either case the shot firer is not exposed to the effects of the explosion.

Time fuse is furnished with a nominal rate of burning of 3 feet per one and one-half minutes. The rate of burning of each shipment of fuse is to be determined by test. Fuse is ignited by a match or fuse lighter. In igniting fuses with a match, the head of the match only gives a high enough temperature to ignite the fuse without fail.

Instantaneous fuse burns at a rate of 120 feet per second. This fuse is recognizable by the **red braid** used in its manufacture. The personnel executing demolitions must never confuse instantaneous fuse with the time fuse.

When it is necessary to splice different pieces of fuse of either kind, the ends to be joined should be cut obliquely. Care must be taken that the powder at the end of the cut does not fall out. The cut ends are placed carefully in juxtaposition, and before closing a few grains of powder should be dropped in and compressed between them. The splice is completed by wrapping with rubber tape if available, otherwise with any material at hand which will keep the ends in contact in their proper position. It is obvious that this splice must be completely protected from strain.

When a line of fuse is to be branched into two the same principles are followed, the double splice being connected and the same precautions taken in making up.

221. **Electrical detonation** is generally more reliable and convenient than detonation with fuses. The electrical current may be taken from any available source of electrical power. The blasting machine furnished will surely detonate 12 tetryl caps in series. The **Standard blasting machine** (fig. 183) generates 2.5 amperes at 45 volts with ordinarily vigorous use. The lead wires from the cap are carefully joined to the lead wire from the blasting machine. Small charges fired electrically are to be connected in **series,** large charges may be arranged either in series or parallel. Circuits arranged for electrical detonation should be always left open until just before detonation. Closed circuits are likely to cause detonation by induced currents from near-by electrical conductors or even from lightning. The electrical relation of the circuit for large charges must often be carefully computed. The tetryl blasting cap with 12-foot lead wires has a resistance of 1.5 ohms and requires a current of 0.4 of an ampere for detonation.

222. **Detonating cord** as issued is a lead tube 6 mm. in diameter, filled with pulverized triton. This cord is used both as a detonating agent for triton and as a means of securing instantaneous detonation of a number of charges. The cord itself must be detonated by a tetryl cap. The triton blocks are strung on the cord, after drilling the cap hole entirely through the triton block with the **cord drill.** Triton blocks can be strung like beads on the detonating cord and used as necklaces to cut posts, etc. Either the electric or the blasting cap may be used to detonate this cord. After the cord is detonated the wave of detonation passes along it practically instantaneously. All triton blocks through which the detonating cord is passed are detonated by it. The connecting up of systems of charges by detonating cord is done by slit connections as shown in figure 180. The cord is cut for this purpose with either a knife or the **cord slitter** (fig. 184). The passage of the detonating wave must occur from a main to a slit and wrapped branch. Wrapping a main about a branch would merely cut a section from the branch and **not** detonate it. Figures 185 to 186a show both the correct and the incorrect method of connecting up a system of charges with cord.

223. **Induced detonation** is of value in arranging simultaneous detonation. This is done by placing a blasting cap in a block of triton and detonating this by means of the mechanical shock in air from a charge detonated nearby. Air will carry over detonation in this manner to varying distances depending on the amount of explosive in the initial charge. To obtain successful **induced detonation** the charge detonated sympathetically must contain a firmly seated open cap whose mouth points directly toward the initial charge and must have no objects intervening. The distance to which induced detonation is practicable is:

Initial charge.	Distance.
	Inches.
1 block triton	24
2 blocks triton	36
4 blocks triton	48
5 blocks triton	60
6 blocks triton	72
8 blocks triton	96

Care must be observed when igniting the fuse of the initial charge of a number of charges to be detonated by induced detonation. The

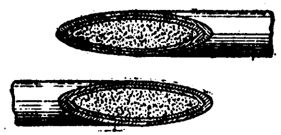


Fig. 179

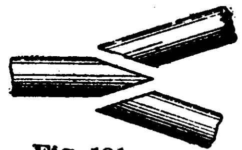


Fig. 180

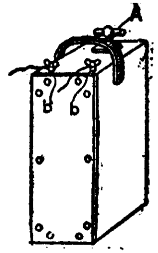


Fig. 183

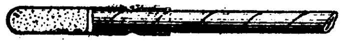


Fig. 181


Fig. 182

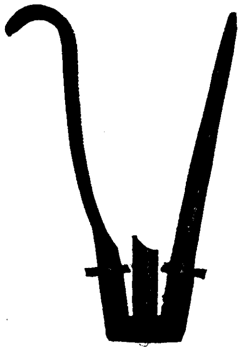
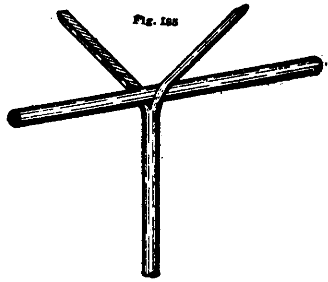
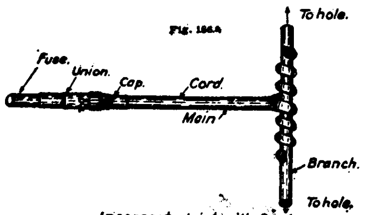
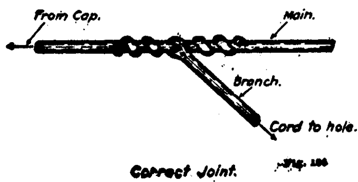


Fig. 184


Beginning a Splice with Cord.
Fig. 185



Incorrect Joint with Cord.
Fig. 186a



Correct Joint.
Fig. 186

flame from the match might be carried by the wind into an unprotected open mouth of one of the caps with disastrous results to the firing party. Figure 188 shows the use of induced detonation in cutting a number of posts.

Figure 189 shows the use of induced detonation in cutting a number of steel I-beam stringers.

Induced detonation of charges makes possible the arrangement of a simultaneous detonation without the use of either instantaneous fuse or electricity.

224. **As noted hereafter,** charges must be arranged as compactly as possible to attain the full effect of the explosion. Nevertheless, triton, both copperplated and noncopperplated, can be successfully detonated even when packed in the original unopened wooden containers and placed beside a box of triton that is then detonated. Figure 190 shows an actual test in which 19 boxes of triton, each containing 108 blocks, or 54 pounds, of triton, were detonated by the detonation of one box detonated with one tetryl cap.

225. Improvised means to attain detonation of certain explosives can occasionally be used. For instance, one of the most useful expedients is shown in figure 191. Here a service cartridge with the bullet extracted is used. The cap end of the shell is seated deeply in the dynamite. The powder taken from the shell is formed in a train as shown. Ignition of the train of powder with a match leads to the detonation of the shell cap and dynamite. Dynamite of 40 per cent or stronger can be detonated in this way.

226. Detonation of explosives other than triton can be obtained in a similar manner to that given for triton. In general, the most powerful detonators obtainable should be used. The use of powerful dotonators increases the power of the detonation of an explosive. At least a No. 6 detonating cap should be used with all classes of dynamites.

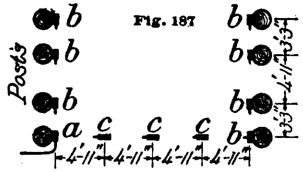
227. **Simultaneous ignitions.**—When a total blast is divided into a number of charges it is important that all should go at the same instant. This will not be easy with time fuse, and that method will not be used unless absolutely necessary. If it is used, certain precautions must be observed to avoid total failure. The fuse must be so laid that the total length from the firing point to each charge will be the same. It will be better to use time fuse to a common point near the charge, and instantaneous fuse from there on. Figures 192 and 193 show typical arrangements. The fuse need not be in straight lines, but must be laid out so that sparks from the burning end can not reach any part in front of it. Though not absolutely necessary with instantaneous fuse, it is well worth while to make different lines as nearly equal in length as possible.

In simultaneous ignitions by electricity the fuses are connected in **series;** that is to say, they are all placed in the same circuit, figure 194. A lead from the firing apparatus is connected to one wire of a fuse on one flank. The other wire of this fuse is connected to a wire of the next fuse, and so on, until the last fuse is reached, the second wire of which is connected back by a lead to the firing point.

Figures 197 and 198 show methods of jointing wires; the former, for temporary use, as a lead to a fuse wire; the latter, for more permanent use. The ends of the wires must always be brightened by scraping with a knife or otherwise. To insulate, wrap with rubber tape, lapping well onto the covering in both directions.

228. **Priming.**—The cap is inserted in a cartridge, usually called **a primer.** Whenever reference is made herein to use of explosives in or near water it is to be understood that under all circumstances the **cap and primer must be kept perfectly dry.** If but one primer is used, it should be placed near the center of the charge when the size and shape of the charge permit it to go in that position. If the cartridges are placed in a drill hole, as in rock blasting and some demolitions, the primer is put in last with the cap end down. The cap may be inserted as shown in figures 195, 196, and

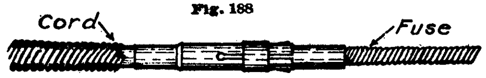
Fig. 187



a Initial detonation.
b Sympathetic with open detonators.
c Charges with open detonators for carrying over detonation.

Demolition of Round Timber Posts by Induced Detonation.

Fig. 188



Union for Blasting Cap

Union for Electric Caps.

Use of Cord with Caps.

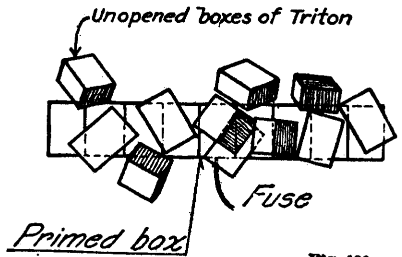


Fig. 190

Detonation of 20 Boxes of Triton.

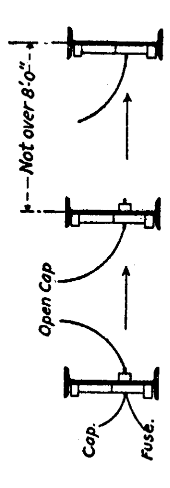
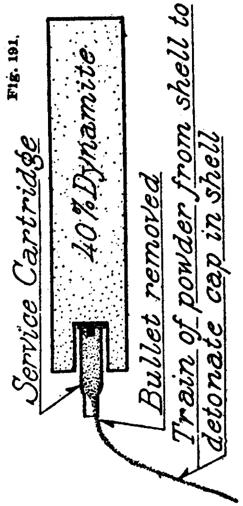


Fig. 189

Demolition of I Beam Stringers by Induced Detonation.

Fig. 191.



Improvised means of detonation.

199. Figure 195 applies to caps fired by **train fuse** and **no other method** may be used with such caps. **The projection** of about one-eighth to one-fourth inch of the cap case above the surface of the powder is **to prevent** the latter from **taking fire** from the sparks of the fuse and burning partially before the fuse goes, which, should it occur, will reduce the force of the explosion or may cause complete failure.

Primers must be prepared at a safe distance from the charge and from the store of caps and should be placed as short a time as possible before firing.

229. **Misfires.**—In case of a misfire there is risk in approaching the holes for several minutes, if electric firing is used, and for several hours in case of firing by fuse. Rules to this effect are laid down where safety to human life is a paramount consideration. They should be recognized in military operations to the extent which circumstances permit. There is also danger in attempting to reprime a charge, especially if tamping must be removed. The danger is reduced by care and by avoiding hard-metal tools and appliances; if possible, the tamping should be removed with wooden tools. In any case, leave a few inches of tamping above the charge undisturbed, then place several sticks of powder and a primer on top of the first charge and fire again. When conditions permit, it is better practice not to attempt repriming, but to place a new charge in a position to do all or a part of the work of the first charge.

The causes of misfires are various. With electricity, if none of the charges explode, the cause is probably due to overloading the machine, or a short circuit in the leads, or a complete break. An effectual, but less probable, cause is deterioration of all the primers. If part of the charges fire and others do not, the cause will probably be found to be either a defective cap, due to moisture or a broken bridge, or a short circuit in the fuse wires, which prevents current going through one fuse but not the others; or the sensitiveness of the caps may not be uniform, and there may be one or more so sensitive that they explode and break the circuit before the bridges of the others have become heated to the point of ignition.

230. **Loading.**—The charge should fill the chamber as nearly as practicable. If drill holes are used, they should be just large enough to permit a cartridge to slip down without jamming. In quarrying, cartridges are frequently slit open before they are placed in the hole, so that with a slight pressure of the tamping rod, they spread and fill the hole completely. **When large charges** of free running powder are to be used, such as dynamite, jovite, and rack-a-rock, the cartridges may be opened and the contents put in bulk into another receptacle. As a rule, however, such charges will be made up by bunching sticks or strings of cartridges and tying them together. **The making up,** and **every possible detail** of preparation, should be done **above ground,** leaving as little to do in the mine as possible. Charges must not be made up into sizes or weights which can not be conveniently carried through the galleries and placed in the chamber.

The charging should be **personally directed** by the responsible officer, and if but one person can get at the charge at a time, he should place the powder himself. Such illumination as may be necessary must be provided by closed lights, with effective precautions against fire. When the primer is placed in the middle of a bulky charge, the wires or fuse must be led out through the powder. Only instantaneous fuse can be so used. If time fuse must be used, place the primer in the middle of one side of the charge so arranged that it must go before any sparks from the fuse can set fire to the powder.

When electric firing is used, the wires of each fuse should be twisted together at the ends to prevent the possibility of a chance current going through the fuse and for identification for connecting to each other and to the leads. Care must be taken that at no stage of the

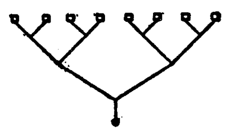


Fig. 192

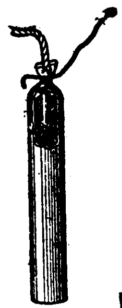


Fig. 195

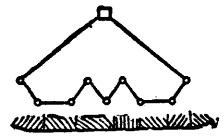


Fig. 193

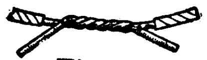


Fig. 197

Fig. 198

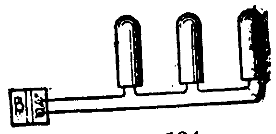


Fig. 194

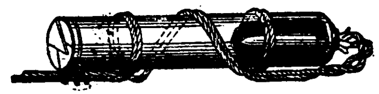


Fig. 196

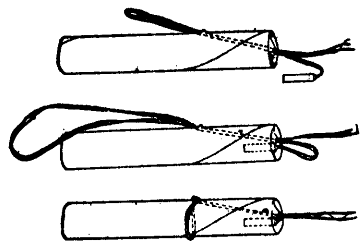


Fig. 199

loading or tamping is a strain brought on any fuse or fuse wires, or any injury done to their coverings.

231. **Tamping** is less important for high explosives than for gunpowder, since the former do a fair proportion of their work without tamping, while the latter does practically none. Light tamping is desirable, however, and may consist of the excavated earth replaced in the communication next to the chamber to a distance of 6 to 10 feet. The use of high explosives facilitates tamping, because so many charges can be placed in drill holes, which are easily tamped.

For drill holes in rock which will hold it, water is the best possible tamping, otherwise sand or stone dust may be used. If the hole points upward, the top should be covered with a board or thick brush to stop the tamping, which is blown out like a projectile. If neighboring ground can not be cleared for firing, the entire surface of the probable crater should be masked by brush or timbers piled upon it and weighted down if necessary.

232. **Effects of explosion.**—It may be assumed as sufficiently exact for present purposes that charges of the same explosive develop total energies directly proportional to their weights. This energy is exerted in all directions in compression of the surrounding medium. The distance at which this disturbance remains sufficient to destroy galleries is called the **radius of rupture,** R. R. The surface joining the ends of these radii is called the **surface of rupture.**

If the charge is large enough, further relief of pressure is afforded by the bodily displacement of a part of the surrounding medium on the side which presents the shortest distance from the charge to the surface. The relief of pressure on one side shortens all radii of rupture which have a component in that direction, but does not appreciably affect those which have no such component. Hence, when material is displaced the surface of rupture is ellipsoidal; when no material is displaced it is spherical. Figure 201 illustrates in a very general way the supposed relations of craters and radii of rupture. It is not based on exact data.

The space left by this bodily displacement of material is called a **crater.** The determination of the crater which a particular charge in a particular place will produce, or of what charge must be put in that place to produce the given crater, or where a given charge must be placed to produce a desired crater, are problems constantly arising in military mining.

Figure 200 shows a cross section of a typical crater in earth. The position of the charge is indicated: *AB* is the surface of the ground; *CD* is the **line of least resistance,** commonly designated L. L. R. or, in formulas, l; *DE* is the **crater radius,** and *CE* the **radius of explosion.** All the elements of the crater are reckoned with respect to the position of the charge and the opening of the original ground surface. This opening for level ground is circular in form and is approximately the intersection of the spheroid of rupture by the ground surface.

Craters are designated as **one-lined, two-lined,** etc., according as the diameter is once, twice, or three times the L. L. R. A two-lined crater is also called a **common mine;** less than two-lined, **undercharged;** and more than two-lined, **overcharged.** A mine which does not break the surface is called a **camouflet.**

When a crater is formed the part of the total work of the charge represented in crater effects is assumed to be proportional to the volume of earth actually moved. As a part is thrown vertically upward and falls back loosely into place (fig. 200), the hole actually left does not represent the earth moved. The total volume moved is assumed, from many experiments, to be represented by the frustum of a cone, shown in section in figure 200, having the crater opening for its larger base, a circle of the diameter L. L. R. for its smaller base and L. L. R. for its height. For each cubic yard of volume of such a frustum a certain weight of explosive is allowed, and it is thus that the corresponding weight of charge is ascertained. **The unit weight** is the quantity of powder required to **throw out 1 cubic yard.** It has been experimentally determined for gunpowder and is deduced for other explosives from their corresponding intensities.

The crater volume, or volume of the conical frustum (fig. 200), may, for any given ratio of height and crater radius, be expressed by the cube of the height, L. L. R., multiplied by a numerical constant, and hence the weight of explosive required to produce a crater of corresponding proportions may also be expressed by l^3 multiplied by a constant. The constant varies with the character of the material, as well as with the proportions of crater.

233. Table II gives constants for various classes of materials and for craters from 1 to 6 lines, the former practically a camouflet and the latter the largest that can be depended upon for results. The table also gives constants from which the R. R. may be determined.

TABLE II.—**CONSTANTS** FOR DETERMINING **CHARGES** AND **RADIUS OF RUPTURE** OF MINES.

Kind of material.	Camouflet, 1-line.	Undercharged, 1½-line.	Common, 2-line.	Overcharged. 3-line.	Overcharged. 4-line.	Overcharged. 5-line.	Overcharged. 6-line.	Remarks.
Light earth	0.005	0.012	0.027	0.081	0.185	0.351	0.594	These numbers to be multiplied by l^3 for charges of 50 per cent dynamite in pounds.
Common earth	.006	.015	.033	.094	.229	.433	.733	
Hard sand	.007	.019	.042	.126	.288	.546	.924	
Hardpan	.008	.023	.050	.150	.343	.650	1.100	
Ordinary brick masonry.	.010	.026	.057	.161	.391	.741	1.254	
Medium rock or good *new* brickwork.	.013	.034	.075	.225	.514	.975	1.650	
Best *old* brickwork	.014	.038	.083	.250	.569	1.079	1.826	
Rad. rupture, Hor.	1.0	1.4	1.7	2.5	3.4	4.0	5.0	These numbers to be multiplied by l for radius in feet.
Rad. rupture, Vert.	1.0	1.0	1.1	1.2	1.7	2.0	2.5	

For gun cotton or 75 per cent dynamite, reduce charges found from above table 40 per cent; for ammonal, reduce 50 per cent.

Strength of triton.—If triton is taken as being 7/5 as efficient as 50 per cent dynamite and the constants given in the formulæ and tables for 50 per cent dynamite be therefore multiplied by 7/7, successful results may be obtained.

The weight of charge may be determined from Table II. It is to be noted that the user of this table must exercise his judgment in classing the soil under the headings given, so that it can not be said that the table gives charges absolutely. If the mine is important, powder not scarce, and no information has been obtained from actual firings in the soil, the tabular charges should be increased 10 per cent for large quantities and 50 per cent for small ones. It is to be remembered that while if more powder than necessary is used the excess may be said to be wasted, if less than the proper amount is used, not only is the total quantity used wasted, but the time and labor spent in getting it into place are also wasted, and the opportunity to gain advantage by successful firing is lost. In all uses of explosives in mining the maxim for the first charge should be, **do not spare the powder.** On the other hand, every charge fired should be carefully observed, and whenever it is ob-

vious that more powder than necessary has been used advantage should be taken of the experience gained to economize powder in future firings. **The worst mistake** that can be made is having the **first charge too small.**

234. **Land mines.**—This term is applied to mines or groups of mines usually formed by excavation from the surface and designed to be exploded at the moment the enemy is over them. Such mines are usually employed in front of defensive positions and in connection with visible obstacles. It is **not permissible** to plant such mines in any ground which is **not obviously** prepared for defense. Any person who ventures on space so prepared does so at his peril, but if there is a road or path open to passage through such ground mines must not be placed therein, or in a place where the explosion would injure persons occupying the road. If any defensive works or recognized obstacles are thrown across the road, indicating that it is closed to traffic, the road may be mined to a reasonable distance in front of them.

The charges are placed deep enough only to avoid artillery projectiles. If no artillery fire is to be expected they may be placed just under the surface. If a bore hole is sufficient the charge is placed at the bottom and the hole well tamped. If an open pit is dug the mine chamber should be in firm ground at one side and the hole back filled and well rammed.

The depth fixed, the charge may be adjusted to give a 2 or 3 line crater. The mines may be in one or more rows. Two rows, 30 to 40 yards apart, are a good arrangement. The intervals between mines in a row should be such that the craters will nearly but not quite join. The positions of the mines should be concealed as completely as possible and further sophisticated by disturbing the ground slightly at points where there are no mines and so situated as to suggest a systematic arrangement.

A fougasse is a land mine in which the volume of the crater is artificially prepared to increase its range and effect. Figure 202 shows the form which has been most used. The earth excavated must be piled around the pit, as shown, and well tamped to prevent the charge blowing out behind the stones. It is not necessary to undercut the bank as shown in the section. If the soil will not stand it may be thrown out to its natural angle and back filled and tamped against the stones. A charge of 25 pounds should scatter a cubic yard of stones over an area 200 by 100 yards.

This form is difficult to conceal and very easily destroyed by the enemy's fire. Another form, with the axis vertical, is shown in figure 203. It is possible to conceal it by sprinkling earth over it, and an automatic firing device may be used with it, which is not practicable with the inclined form.

235. **The igniting means** may be instantaneous fuse or electricity. Fuses or wires should be laid in trenches 1 to 3 feet deep. Mines are classed with respect to the method of firing as **judgment** and **automatic. Judgment** mines are controlled from a firing point and can be fired only at the will of the operator. **Automatic** mines are arranged to be fired by the disturbance of some apparatus in or near them. Automatic and judgment firing are often combined for the same mines. **If firing by cap,** the automatic firing device takes the form of a **mechanical trigger,** which may be operated by the pressure of feet on the ground over it, or by the pulling of a wire stretched along the line at such height as to be tripped by the feet. With electric firing this device is called a **circuit closer,** and the actuating force operates to close a contact which completes a metallic circuit from the battery to the fuse.

Planting and operation of land mines will ordinarily be the work of technical troops supplied with approved apparatus.

236. **Mine tactics.**—In siege operations mining is done at close quarters, and is, or should be, opposed by countermining by the enemy. There is then a double purpose in view—to reach the original objective by placing the charge where intended and firing it, and while so doing to detect and circumvent any attempt of the enemy to interfere or to prosecute any enterprise of his own.

The only information of neighboring operations which is obtainable results from the **sound of working** carried through the earth. In compact soil an ordinary blow of a pick can be heard at a distance of 40 feet, and the most careful working is audible to a distance of 20 feet. Other sounds, such as rumbling of trucks, and especially tamping, can be heard farther. These distances vary with the character of the soil and the skill of the listener. When more than one gallery is driven they should be parallel and not farther apart than twice the range of hearing, so that an enemy's gallery penetrating between them will be heard from one or both. Returns may be run out from the extreme galleries to detect the sound of working on the flanks. Such galleries are called **listeners.** They should not be large.

Efforts must be made to detect the enemy's working and to avoid, so far as possible, giving him like information. At occasional and irregular intervals all work should cease, all extraneous sounds be cut off, and men with quick and trained hearing should listen for sounds of working and estimate the distance and direction. A map of the galleries should be kept, and whenever two headings are approaching, listening should be done in them and the estimates made by the men compared with the measurements on the map as a check on the range of hearing. Accuracy of perception of the sounds may be tested by tapping messages across.

When hostile parties have approached within destructive range of each other the one who fires first is the winner, but the nearer he is or the longer he holds his fire, the more complete the victory. Each party will be on the alert to discover when the other party is getting ready to fire, and hence the greatest care must be taken to sophisticate the sounds connected with loading. Digging should continue at some point near the end, and all movements of trucks or other operations which make a noise should be continued not less frequently, and certainly not more frequently, than during the digging. Especially should tamping be cautiously done. **The most probable mistake is premature firing,** and it should be impressed upon all concerned that it is **better to come into actual collision** with the enemy's miners than to fire prematurely.

Galleries are much more vulnerable to a side than an end attack. If the enemy's heading can be located, an attempt should be made to get a position on one side of his gallery. The best position is nearly abreast of the end, a little in rear, so that if he is still digging a considerable length of his gallery will be destroyed, or if he is loading or loaded his mine will be exploded.

For long galleries the difficulties of ventilation and earth disposal may make it advisable to take a new departure. The heads of galleries are brought on a line, or nearly so, branches run forward from each so as to end at intervals of one and one-half times the depth below the surface, charged for common mines and fired simultaneously. An elongated crater is produced, which becomes a lodgment for new galleries as well as an advanced parallel in any system of surface approaches. The old galleries are reopened to form rear communications. It has frequently happened that entire underground operations have been directed to the single purpose of forming such an advanced trench in a position which could not be reached on the surface.

It will rarely be possible to get close enough to do serious damage with a camouflet, though in some cases it might be advantageous to avoid breaking ground at the surface. The maximum camouflet charge—one-sixth to one-eighth of common mines—gives an H. R. R. somewhat less than the L. R. R., which will usually be not more than 15 feet, while a 6-line crater has an H. R. R. of 5 times L. R. R. As countermining will usually result in a crater, consideration must be given to its situation with respect to the surface work so that it will be an advantage if possible and certainly not a detriment.

DEMOLITIONS.

237. **Military demolitions** have for their purpose to destroy or make unserviceable any object in the theater of war the preservation of which would be unfavorable to the army or favorable to the enemy, excepting always objects neutralized by international convention or the laws of war.

The principal objects of demolition may be divided into **two general classes,** viz:

Natural or **artificial objects** having **no intrinsic** or **permanent value,** such as accidents of ground and structures of purely military character; and

Natural or **artificial objects** having intrinsic or permanent value, or **adapted to useful purposes** in time of peace, such as buildings and communications.

Demolition is permissible only under a **military necessity.** For the first class of objects above the military necessity is obvious, since the destruction is aimed directly and exclusively at the enemy's fighting efficiency.

For the second class, the destruction affects others besides the armed enemy, and for this class the existence of a military necessity justifying demolition can not be presumed but must be determined at the moment, and the amount and character of destruction or disablement explicitly ordered by competent authority.

Demolitions of a local character, which have no effect elsewhere, may be made on the order of the immediate commander, as may also demolitions of a more serious character, but which are necessary to the safety of a local force. For example, a small force in retreat may interrupt a bridge to avoid capture, but the destruction should go no farther than is necessary to produce the result immediately desired by detaining the pursuers long enough to enable the pursued to make their escape. Demolitions which are intended to, or in their ultimate consequences may affect a larger force or a greater territory, must be ordered by the commanding general of an army or other force operating independently. In case of doubt, orders should be sought from the highest accessible commander. An officer upon whom work of demolition is devolved should, if not provided with proper orders, ask for them.

238. **Methods employed.**—Demolitions may be made by **fire,** by **mechanical means,** or by **explosives.** Fire is the only recourse when absolute destruction is necessary, as in case of food supplies, munitions of war, structural materials, etc. Soluble matter, as gunpowder, sugar, salt, etc., might be destroyed in water, but this method is laborious. Burning is equally effective and much easier. For quick results with slow-burning materials a quantity of highly combustible stuff must be collected. A small fire gains headway very slowly and much time is lost. Care must be taken that the fire does not spread to objects not intended to be destroyed.

239. Demolition by mechanical means is too simple to require, and too varied to permit, detailed description. Reference is made to a few cases in which the best method may not be obvious.

Abatis is difficult to destroy. If the trees are dry, time suffices, and concealment is not essential, fire is best; otherwise, if working from the front, cut up and carry away enough trees to make a passage through. If working from the rear, loosen the fastenings of the butts and haul away bodily with ropes.

Wire entanglements must be cut with nippers, the more and shorter the pieces the better. Wire may be cut with an ax or machete if a block of wood is held behind it as an anvil. **Trous de loup** are leveled by shoveling the walls into the pits, or bridged with planks, fascines, or other materials.

Palisades and **stockades** may be cut down with axes or saws, or the earth may be dug away from one side and the logs pulled over.

Railroads.—Operations may be directed against rolling stock, bridges, culverts, tunnels, or track, or accessories, such as water stations, telegraphs.

Locomotives are temporarily disabled by removing valves or other small vital parts; permanently by building a fire in a dry boiler or by detonating a charge of explosive in the boiler. In haste, piston or connecting rods, links, etc., may be destroyed by explosives, or a hole may be blown in the bottom of the tender tank. Cars may be burned or wrecked by collisions or derailment. The best places are in deep cuts or tunnels. A head-on collision in a tunnel will put it out of use for some time.

Wooden bridges may be burned or small ones may be pried off their seats by levers or dragged off with tackle.

Track may be destroyed by taking it up, burning the ties, heating the rails on fires and twisting them with bars through the bolt holes, with a chain and lever, or a hook and lever. Twisting is much better than bending, as twisted rails must be rerolled before they can be used. The rail should be hot for the greater part of its length, so as to take a long twist. **A quick track demolition** requiring considerable time to repair, but not injuring the track material, may be made by loosening the ties over a stretch of track, taking off the end fishplates, putting a line of men along one side, two men to each tie, and turning the track over bodily. This plan works best on a high embankment.

Telegraph lines are temporarily disabled by **breaks,** in which wires are cut, **grounds,** in which the wires are connected to the ground, and **crosses,** in which a metallic connection is made between the wires. **A ground** may be made by connecting a wire to the rail or to a bar or plate of metal in damp earth. Copper is best. A connection with water or gas pipe forms a ground. All faults should be carefully concealed from view, so as to prolong the time necessary to locate them. If a raid is made on a telegraph office, remove the instruments, bare and brighten the ends of all wires, and tie them together with a wrapping of brightened copper wire. Incoming and outgoing wires should be tied separately.

To destroy a telegraph line cut down and burn poles, cut and tangle wires, and break insulators.

240. **Demolition equipment of engineer troops.**

Company tool wagons.	On the 2 tool wagons of pioneer company.	On the 1 tool wagon of mounted company.
Augers, earth, handled	2	1
Augers, ship, ½-inch, handled	2	1
Bars, pinch, large	2	1
Bars, wood, tamping	2	1
Boxes, cap	2	1
Boxes, match	2	1
Chisels, cold	2	1
Circuit detectors	2	1
Crimpers	2	1
Drills, single-bit, long	2	1
Drills, single-bit, short	2	1
Hammers, sledge, 8-pound	4	2
Magneto exploders	2	1
Pick mattocks, E. D. pattern, "intrenching," handled	4	2
Reels, wire, firing	2	1
Shovels, E. D. pattern, "intrenching"	8	4

Demolition equipment of engineer troops—Continued.

Company tool wagons.	On the 2 tool wagons of pioneer company.	On the 1 tool wagon of mounted company.
Spoons, miner's, long	2	1
Wire, firing, double lead, No. 14, feet	2,000	1,000
Cord, drill	2	1
SUPPLIES.		
Caps, tetryl, nonelectric	100	50
Caps, tetryl, electric	200	100
Explosive, pounds	200	100
Fuse, Bickford, feet	200	100
Fuse, instantaneous, feet	200	100
Matches, safety, boxes, dozen	1	½
Tape, insulating, rolls	2	1
Twine, hemp, 2-ounce balls	2	1

Pack train.	On the 4 mules of pioneer company pack train.	On the 8 mules of mounted company pack train.
Augers, ship, 1¾-inch, handled	2	4
Bars, pinch, small	2	4
Boxes, cap	4	8
Boxes, match	4	8
Boxes, pack, Nos. 2 and 3	4	8
Buckets, canvas	2	4
Chisels, cold	2	4
Crimpers	4	8
Drills, single-bit, short	2	4
Hammers, sledge, 8-pound	2	4
Knives, clasp	4	8
Pick mattocks, E. D. pattern, "mining," handled	2	4
Pliers, side-cutting	4	8
Rolls, canvas, for tools	4	8
Shovels, E. D. pattern, "mining"	2	4
Spoons, miner's, short	2	4
Cord drill	4	8
Cord slitter	4	8
SUPPLIES.		
Caps, detonating	200	400
Cord, detonating, spools	8	16
Explosive, pounds	180	360
Fuse, Bickford, feet	400	800
Fuse lighters, Bickford	120	240
Matches, safety, boxes, dozen	2	4
Rope, manila, ½ inch diameter, 18 feet lashings	4	8
Twine, hemp, 2-ounce balls	4	8
Unions, detonating cord	48	96
Wire, copper, No. 30, ¼-pound spools	4	8

241. In the **execution of a demolition with explosives** there must be considered:

1. **The object of the demolition.**
2. **The relation of the charges, their individual and joint effect, their location and accessibility, the nature of the tamping, and the distance of the personnel when detonation occurs.**
3. **The nature of the material to be blasted and the precautions required in placing the charges and protecting them from moisture.**
4. **Computation of the individual charges.**
5. **Method of detonation.**
6. **The requirements of time for executing the work, personnel, explosive, caps, fuses, etc., and building material.**
7. **A few instructions for the personnel which is to detonate the charge.**
8. **Final arrangements and precautions to be taken in cases of important demolitions. These should be prescribed by orders of the commanding officer.**

242. The **text of this manual** gives the data required for the proper consideration of nearly all of the above. Only general rules are laid down. The details for working out each particular demolition will vary greatly.

243. The **object** of the demolition can only be properly attained through accurate grasp of the tactical situation. It is unpardonable to completely wreck a line of communications which friendly troops may require in the near future. It is likewise unpardonable to fail to use every means to wreck a line of communications that is to pass immediately into hostile control for a long future period. **Demolitions of bridges or other important structures should not be executed except by authority of the commander in the area involved, or in extreme emergency.**

244. The two general **types of charges are: Concentrated charges** and **charges in a row. Concentrated charges** in which the explosive is bunched are the rule. One cap in one triton block will detonate completely all blocks placed closely around the primed block. For maximum effect, the charge should approximate the cubical shape.

245. **Charges in a row** or **small distributed charges** are the exception. Their adaptability is discussed hereafter. If the blocks are placed closely together, one block detonated will detonate the entire row. As a precaution, a string of blocks placed on detonating cord may be placed along the entire row.

If the charge is placed in small **drilled holes**, the triton stick is to be used. Otherwise the triton block is admirably adapted for bunching into masses of the most effective form.

In **priming** the charge, the cap is to be firmly seated in the cap hole, with the fuse (if used) securely crimped in the cap or the lead wires connected securely (if electrical detonation is used). It is notable that triton will usually detonate with a No. 6 commercial cap if a boosting charge of powdered triton is used. If detonating cord is used, the cord must be dry when passed through the triton block. Methods of priming dynamite with both blasting and electric caps are shown.

246. The problem of securing **simultaneous detonation** is one calling for much practice. The various methods of obtaining simultaneous detonation are, in order of excellence:

First. Electricity with detonating cord.
Second. Electricity.
Third. Time fuse with detonating cord.
Fourth. Time fuse with induced detonation.
Fifth. Time fuse with instantaneous fuse.
Sixth. Time fuse.

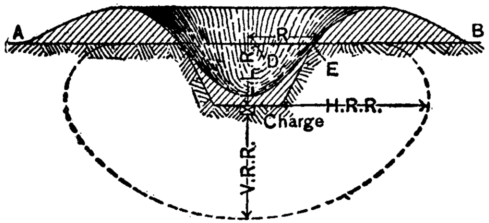


Fig. 200

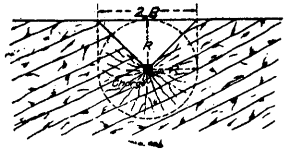


Fig. 204

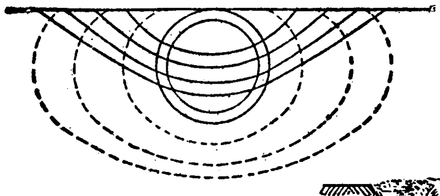


Fig. 201

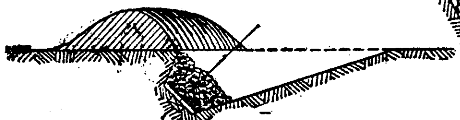


Fig. 202

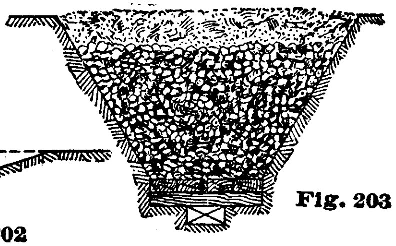


Fig. 203

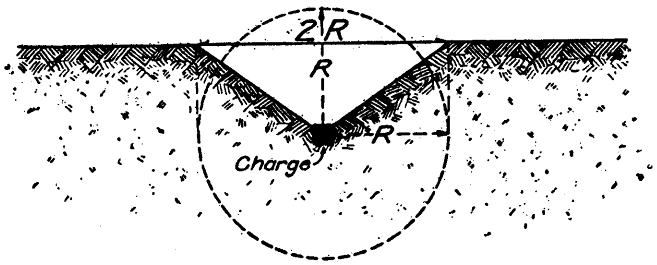
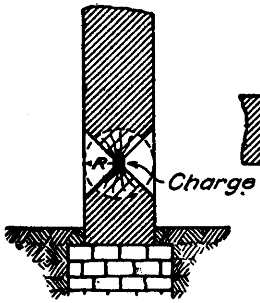


Fig. 205



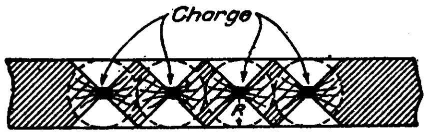
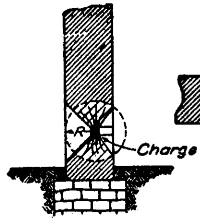


Fig. 206



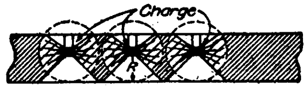
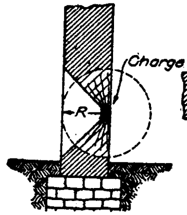


Fig. 207



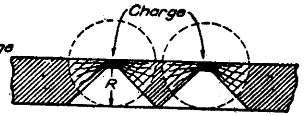
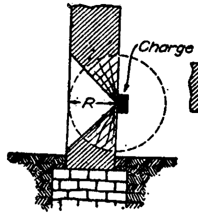


Fig. 208



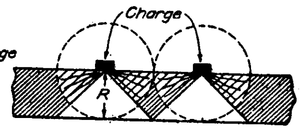


Fig. 209

TYPICAL LOADING

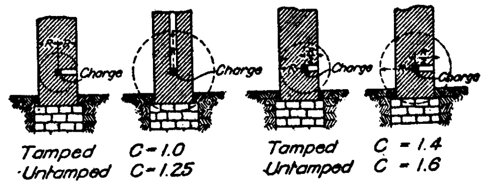


Fig. 210

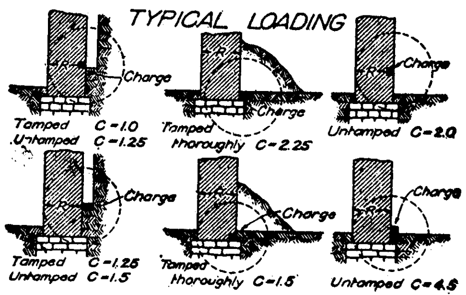


Fig. 211

247. **Calculation of quantity of explosive.**

Let **R=radius of rupture in feet.**
Let **N=number of one-half pound blocks of triton required.**
Let **K=a factor depending upon the material blasted.**
Let **C=a factor depending upon the location and tamping of the charge.**

Then $$N=5/4\ R^3\ K\ C$$

This formula gives a quantity of charge sufficient to blast out a cone of material, the center of charge being the apex and the base having a radius equal to R. The altitude of the cone equals the depth at which the charge is placed within the material. Such a charge will be referred to as **a breaching charge.** The radius of rupture so determined is the radius of a sphere within whose surface all material is completely shattered. The center of the sphere is, of course, at the center of the **charge.** Figure 204 shows a charge placed at a depth of R; figure 205 shows a charge placed at a depth less than R.

Figure 206 shows the effect of blasting a masonry wall with a series of charges inserted in holes driven to the center of the wall.

In figure 207 the holes are driven but a portion of the distance to the center of the wall, and in figure 208 the charges are placed in cavities in the face of the wall.

In figure 209 the charge is placed against the face of the wall. R is indicated on each of the figures. This formula is of general use in computing charges for land mines and for the demolition of structures of masonry and of earth embankments and for the blasting of rock.

248. **The value of K, the material factor,** is to be selected from the following table:

Good masonry, concrete or rock.

	Value of K.
R under 3 feet	0.5
R between 3 and 5 feet	.4
R between 5 and 7 feet	.35
R over 7 feet	.30
Poor masonry, shale or hard pan (all values of R)	.30
Ordinary earth (all values of R)	.07
For very **dense concrete or first-class** masonry multiply above factors for good masonry by	1.3
For **reinforced concrete** multiply above factors for good masonry by	2.0

249. The value of C is chosen so as to take into account the location of the charge and the extent of the tamping. C equals 1.0 for charges placed in a bored hole and thoroughly tamped as in a land mine. (See figs. 210 and 211.)

250. **The charge** may be computed, but to save time the charts A, B, and C (figs. 212, 213, 214) are generally to be used. These give the number of blocks required for values of R from 1 to 35 feet.

These curves are to be used as follows:

1. Place a straight edge horizontally cutting the left side of the cross-section paper at the value of R.
2. At the intersection of the straight edge and the curve labeled "5/4 R³" drop a line vertically and intersect the line labeled with the selected value of C.
3. Project this point horizontally until the line labeled with the selected value of K is intersected.

Fig. 212

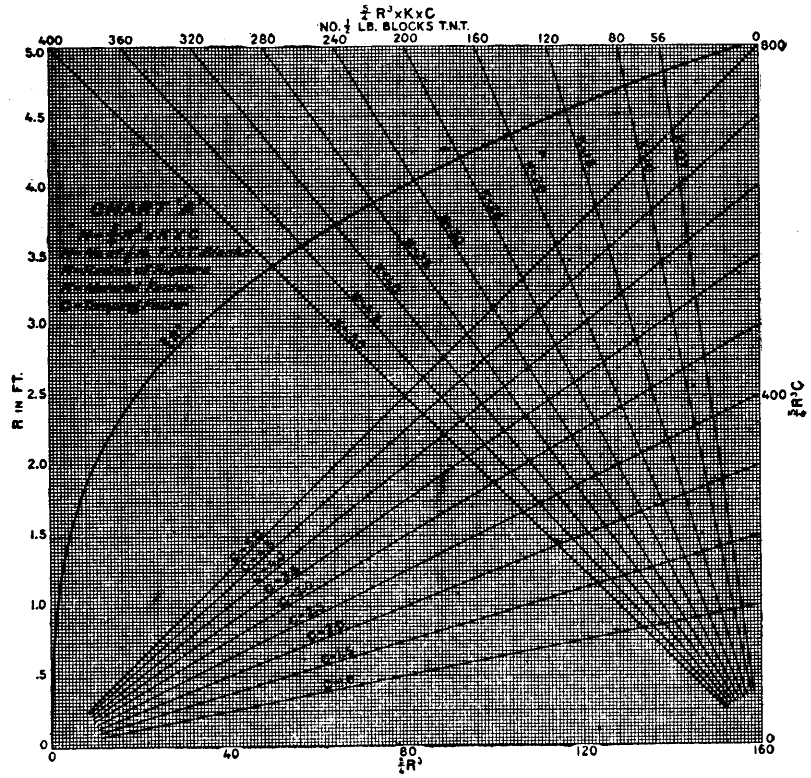
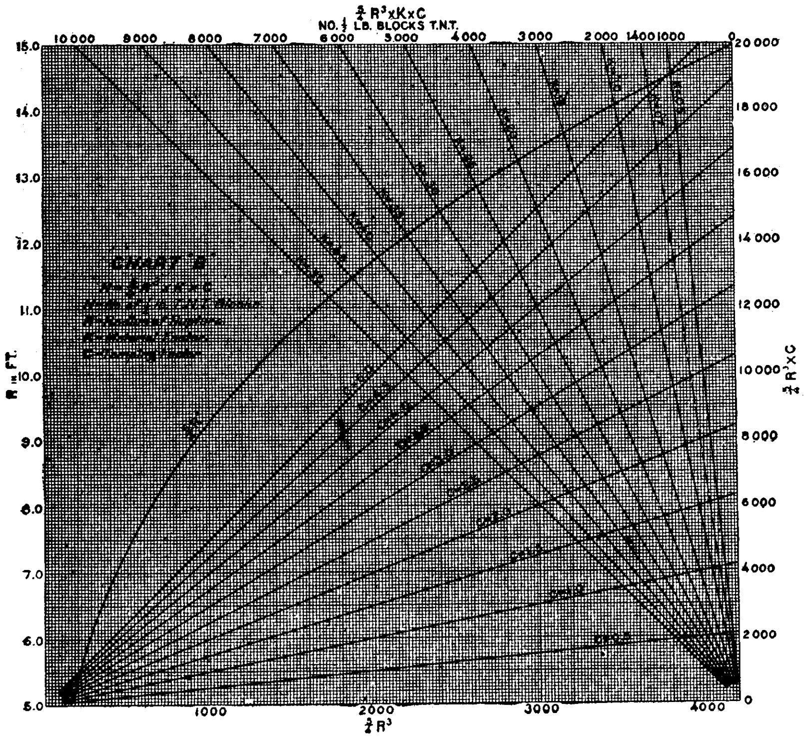


Fig. 213



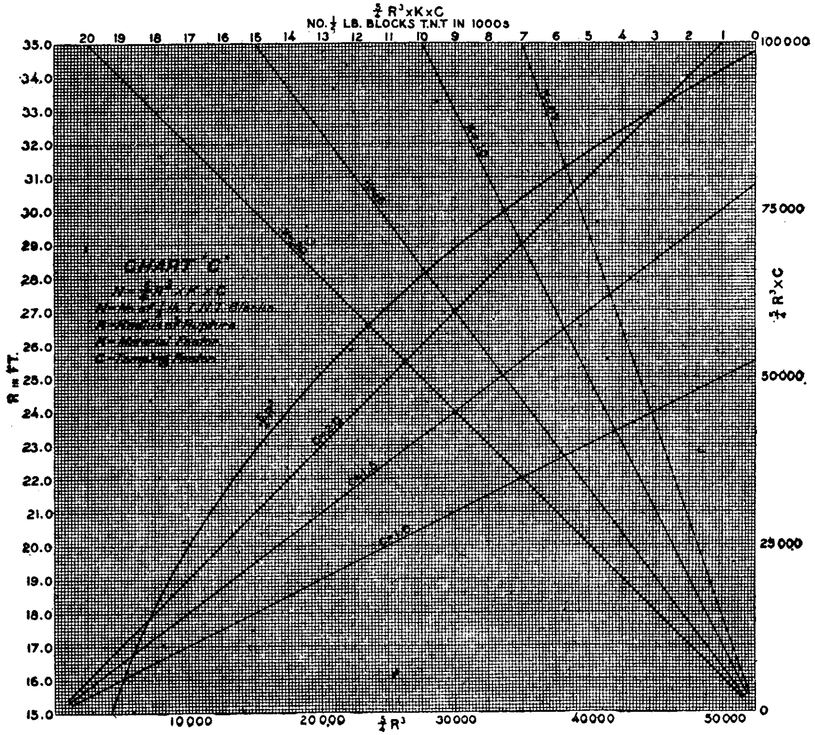
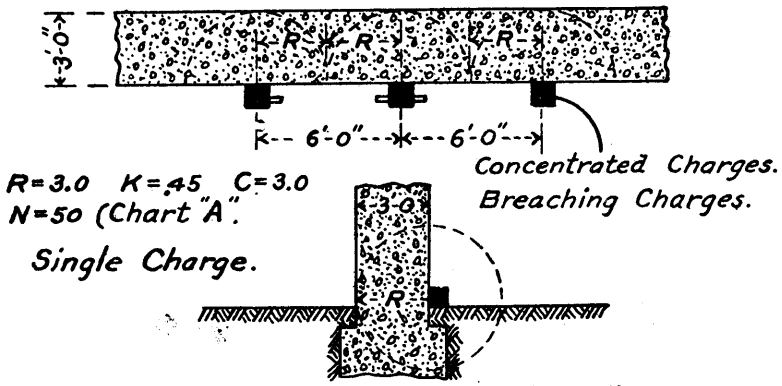


Fig. 214



Demolition of Masonry Wall.

Fig. 215

4. Project this point vertically upward and read on the scale at the top of the cross-section sheet the number of **half-pound blocks** of triton required.
5. If the material blasted is reinforced concrete or very dense concrete, determine N for good masonry and then multiply by 2.0 for reinforced concrete or by 1.3 if very dense concrete.
6. Figures 215 to 218 illustrate the use of this curve.

251. The curves enable K and C to be varied readily, and the experience in actual demolitions will readily determine valuable data as to more accurate values of K and C. Demolitions made in peace time are always to be viewed as experiments conducted with a view to securing information as to the value of K and C.

252. **Shattering charges** differ from breaching charges in that the material is only loosened and is not blasted away. Such charges are to be used in quarrying, as an aid to mechanical demolitions, and in mining. The shattering effect extends one and one-half to two times R. Figure 219 shows a breaching charge to the left and the same charge as a shattering charge to the right.

Figure 220 shows a charge placed in a counter mine to destroy the hostile drift M. This charge must be kept at least 2 R below the surface to avoid shattering the surface of the ground.

253. **Distributed charges, breaching charges—Charges in a row** are to be used to breach through slabs or walls of masonry or concrete. The formula for the computation of such charges is **$N = 4\ R^2 \cdot K \cdot C$ per yard.** The symbols have the same meaning as given for the formula for breaching charges. K and C have the same values as given in the formula for breaching charges. For reinforced concrete K is doubled, as previously noted, and in addition a value of R is chosen equal to one-fourth times the thickness of the slab or wall.

254. **Chart D** (fig. 221) is to be used in computing the charge required. Its use is similar to charts A, B, and C for concentrated charges. (See figs. 222 and 223.)

255. **Charges in a row** require about twice as much explosive as concentrated charges. Their use is the exception and generally to be restricted to the demolition of thin slabs or walls.

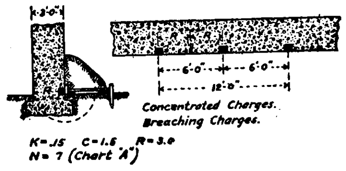
256. **Timber.—Timber** can be destroyed by fire or by cutting. Trees 16 inches in diameter or under are more quickly destroyed by cutting than by explosives. Explosives are used principally where the demolition has to be delayed until a given moment and then executed instantly. Single charges are computed as follows:

Charge outside timber, $N = .03\ D^2$,
Charge inside timber, $N = .008\ D^2$,

in which N = number of **half-pound** blocks of triton and D = least diameter of timber **in inches.** If the timber be green, tough, or knotty, the charge is increased 50 per cent. A rough rule for compressed triton charges is to allow six blocks per square foot of cross section for outside charges and two blocks per square foot for inside charges. For timbers 24 inches or less in diameter bore a hole to within 1 inch of the opposite face and fill to 1 inch from the top with triton.

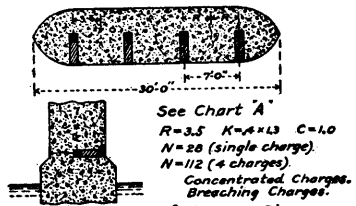
257. If triton sticks are used and inserted in bore holes in the timber, the formula becomes **$N_1 = .01 \times D^2$**, in which **N_1 = the number of sticks of triton weighing .4 of a pound each** and D = the least diameter of the timber **in inches.**

Figure 224 illustrates the placing of charges for the demolition of a timber bent.



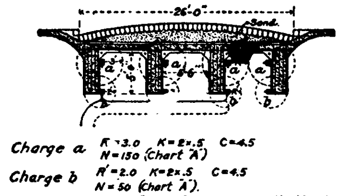
Demolition of Masonry Wall.

Fig. 216



Demolition of Masonry Pier.

Fig. 217



Demolition of Reinforced Concrete Viaduct.

Fig. 218

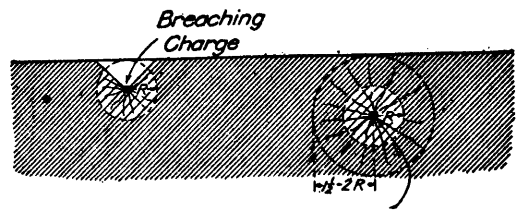
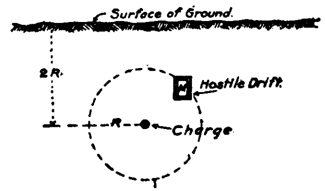


Fig. 219



Explosions in Counter Mines.

Fig. 220

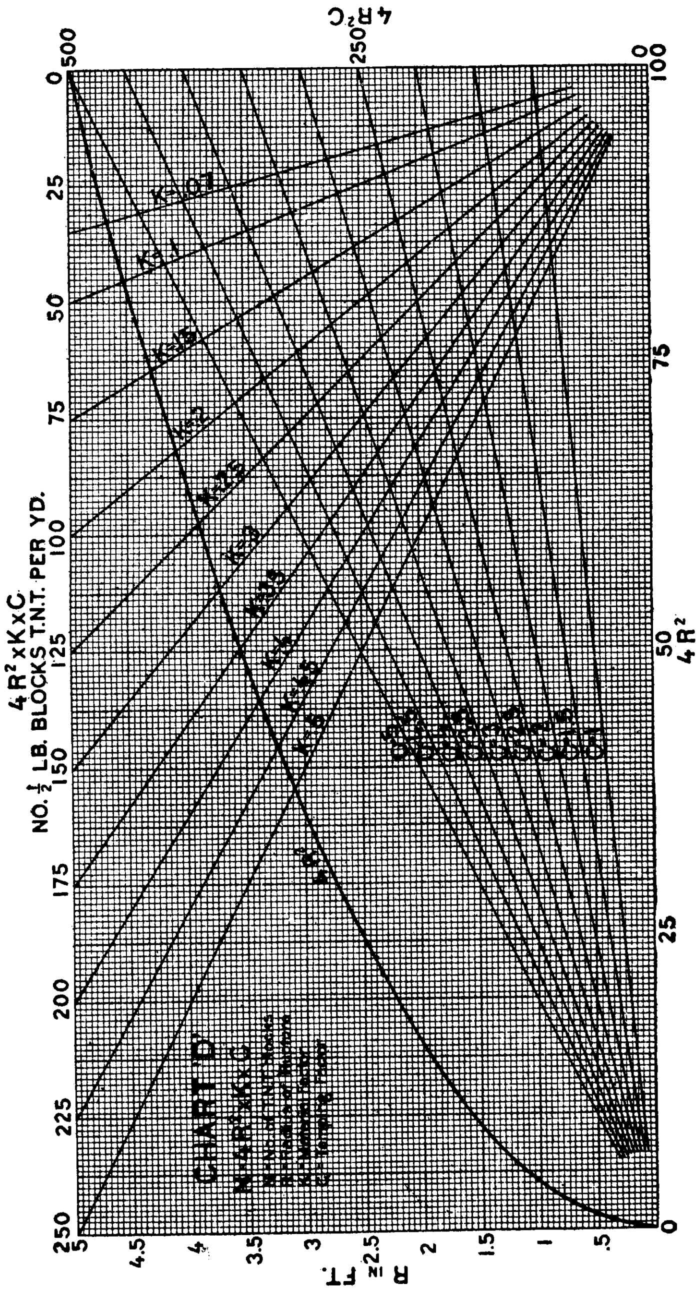


Fig. 221

The following table gives the value of D^2 and is to be used in computing the charges required:

VALUE OF D^2.

D.	D^2.	D.	D^2.	D.	D^2.	D.	D^2.
6	36	14	196	22	484	30	900
7	49	15	226	23	529	31	961
8	64	16	256	24	576	32	1,024
9	81	17	289	25	625	33	1,089
10	100	18	324	26	676	34	1,156
11	121	19	361	27	729	35	1,225
12	144	20	400	28	784	36	1,296
13	169	21	441	29	841		

Figure 225 illustrates the placing of charges for the cutting of a number of timber stringers.

Figure 226 shows the charges placed for the destruction of round timbers by inserting the triton in bored holes.

258. **Steel.**—Bessemer steel crystallizes, breaks, and throws its fragments generally away from the explosive. Open-hearth steel tears and may throw fragments in any direction. These fragments are frequently large and projected with force enough to carry them from 400 to 1,000 yards or more. Extra precautions must be taken to shield the firing detachment. Tree trunks 12 inches or more in diameter make good field shelter.

For the purpose of computing the charges required to cut heavy steel I-beams and built-up steel girders and columns the following formula is to be used:

$N=A \times \frac{3}{4}$.

N=number of *one-half pound blocks* **of triton required.**

A=area in *square inches* **of the cross section of the steel member to be cut.**

A number of illustrative examples are attached, by means of which the use of the formula will be evident. It is to be noted that the charge must be placed against the steel member so that the greatest quantity of explosive will be near the heaviest part of the cross section.

To prevent an overestimate of what can be done with the quantity of triton carried, the study and use of the above formula are recommended.

A handy rule, applicable only to $1\frac{3}{4}$ by $1\frac{3}{4}$ by $3\frac{3}{16}$ inch triton blocks, is that a line of blocks entirely across the plate will, if laid on side, cut a 1-inch plate, or, if stood on end, will cut a $1\frac{1}{2}$-inch plate. Up to and including five rows, each additional row of blocks on side adds $\frac{1}{4}$ inch and each additional row of blocks on end adds $\frac{1}{2}$ inch to the thickness of the metal which can be cut.

259. **Steel bridges—Trusses.**—In destroying a bridge, try to cut the complete cross section. Charges should be placed in the upper and lower members of the trusses on both sides of the road. The best place for rupture is near the abutments where the chords have the least cross section, except in a cantilever bridge, which should be cut over the towers. By choosing the panel points for the location of the charges, they may easily be confined and tamped, and maximum results will be obtained with the smallest number of charges.

In the case of a heavy bridge, the amount of explosive carried will frequently be adequate to cut only one chord. In this case, the chord

in tension is cut; that is, the lower chord, except in the case of a cantilever. Members in tension are nearly always made up of bars of rectangular cross section and should be cut at a point near the abutment where the least cross section of steel is used. A cantilever truss is destroyed by cutting the upper chord near the tower.

Figures 227 and 228 show the main members in both a through and deck railroad bridge, each of simple design.

Figures 229 to 237 show amounts of explosive and methods of placing same to destroy steel bridge members.

260. **Railroads.**—One block of triton laid against the web will take a 6-inch section out of a 90-pound rail that is spiked to ties. One block on top will not break it, but two will take out a 6-inch section.

In order to interrupt traffic, break as many rails as time will permit. It is a good plan to break each rail in two places, several feet apart. If the charges are placed on opposite sides of the rail, the fuses can be lighted at the same time, and the first charge that detonates will not displace the other.

Figure 238 shows a charge placed at the fishplate connections. Use four blocks of triton, placed close together with one cap, as shown. Earth should be used to tamp the charge. This charge will render useless two rails and their connection.

Figure 239 shows the location and quantity of a charge for destroying a switch.

Figures 240 and 241 give the same information for a frog and crossover, respectively.

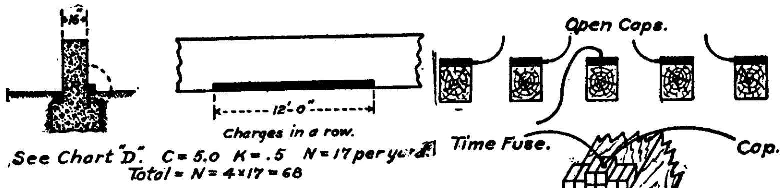
To destroy the railroad roadbed, the best location of the charge is in a culvert, such as are generally found under heavy fills. Table A, following, gives the charges required in such cases, and figure 242 shows the location of the charge. The charge can also be computed by the use of the formula for breeching charges (charts A, B, and C).

TABLE A.

LOADING FOR DEMOLITION OF RAILROAD ROADBED AT A CULVERT.

Distance of charge below roadbed.	Single-track line roadbed 15 feet wide.		Double-track line, roadbed 28 feet wide.			
	Number of charges.	Number of blocks of triton in charge.	Number of charges.	Distance C. to C. charges.	Number of blocks of triton in charge.	Total number of blocks of triton required.
Feet.				*Feet.*		
8.0	1	320	2	16.5	225	450
10.0	1	440	2	16.5	320	640
11.5	1	585	2	16.5	440	880
13.0	1	760	2	16.5	585	1,170

261. **Blocking a tunnel** effectually interrupts railroad traffic. If the tunnel is lined with masonry or passes through sound rock, arrange for a head-on collision at the center of the tunnel between a car or locomotive and another moving locomotive. In case of a double-track tunnel, such a collision should occur on each track.



Demolition of Masonry Wall.
Fig. 223

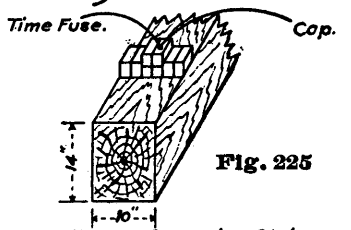
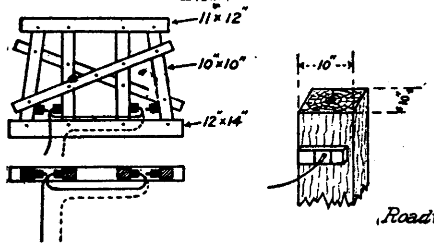


Fig. 225

Demolition of Wooden Stringer



Demolition of Timber Bent
Fig. 224

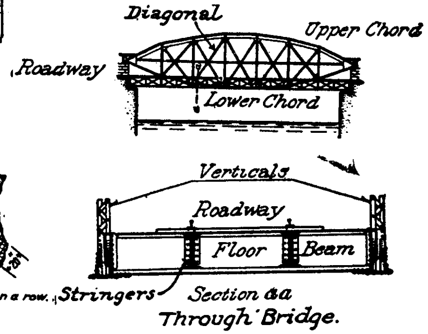
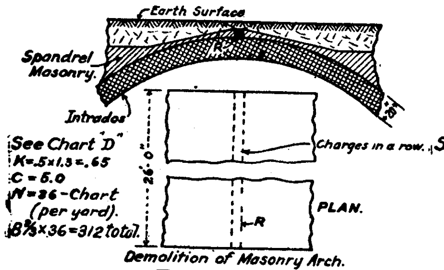


Fig. 227



Demolition of Masonry Arch.
Fig. 222

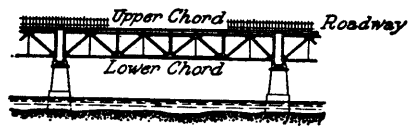


Fig. 228

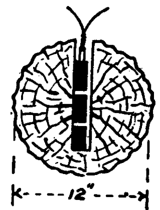
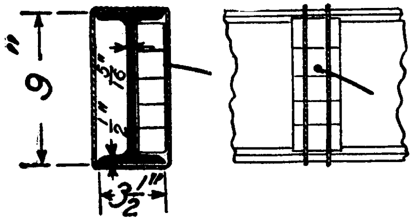


Fig. 226

Fig. 229

Steel I Beam



$(9'' - 1'') \times \frac{5}{16}'' = 2.5\,\square''$

$(3\frac{1}{2}'' \times \frac{1}{2}'') \times 2 = 3.5\,\square''$

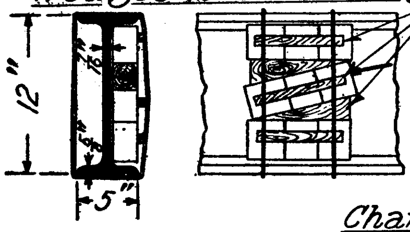
$6.0\,\square''$

$\text{Charge} = \frac{3}{4} \times 6.0\,\square'' = 4.5$

Charge 5 Blocks T.N.T.

Fig. 230

Wedges to bind charge



$(12'' - 1\frac{1}{4}'') \times \frac{7}{16}'' = 4.7\,\square''$

$(5'' \times \frac{5}{8}'') \times 2 = 6.3\,\square''$

$11.0\,\square''$

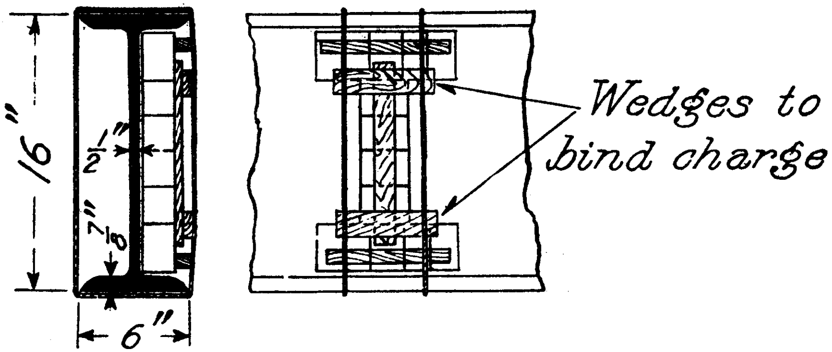
$\text{Charge} = \frac{3}{4} \times 11.0\,\square'' = 8.25$

Charge 9 Blocks of T.N.T.

Steel I Beam

Fig. 231

Steel I Beam



Computation of charge

$(16'' - 1\frac{3}{4}'') \times \frac{1}{2}'' = 7.1 \text{ sq.in.}$

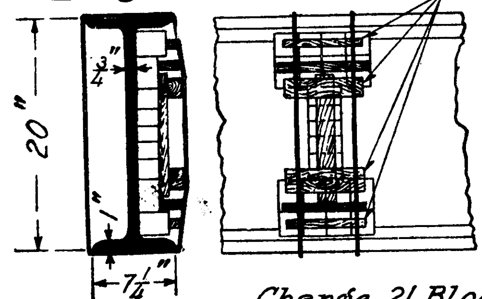
$2'' \times 6'' \times \frac{7}{8}'' = 10.5$

17.6

$\text{Charge} = \frac{3}{4} \times 17.6 \text{ sq.in.} = 14 \text{ Blocks T.N.T.}$

Fig. 232

Wedges to bind charge



$(20'' - 2'') \times \frac{3}{4}'' = 13.5\,\square''$

$(7\frac{1}{4}'' \times 1'') \times 2 = 14.5\,\square''$

$28.0\,\square''$

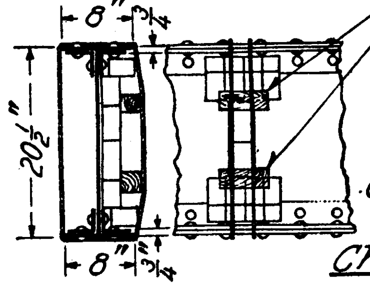
$\text{Charge} = \frac{3}{4} \times 28.0\,\square'' = 21.0$

Charge 21 Blocks of T.N.T.

Fig. 233

Built up Girder

Wedges to bind charge



$$\left(20\tfrac{1}{2}'' - \tfrac{3}{4}''\right) \times \tfrac{3}{8}'' = 7.4 \text{ sq.in.}$$
$$8'' \times \tfrac{3}{8}'' \times 2 = 6.0 \text{ sq.in.}$$
$$7'' \times \tfrac{3}{8}'' \times 4 = \underline{10.5} \text{ sq.in.}$$
$$\text{Total } 23.9 \text{ sq.in}$$

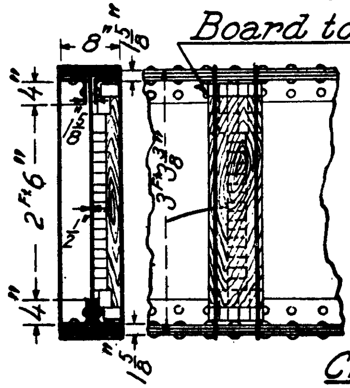
$$\text{Charge} = \tfrac{3}{4}'' \times 23.9 = 17.9$$

Charge 18 Blocks of T.N.T.

Fig. 234

Heavy Built up Girder

Board to bind charge



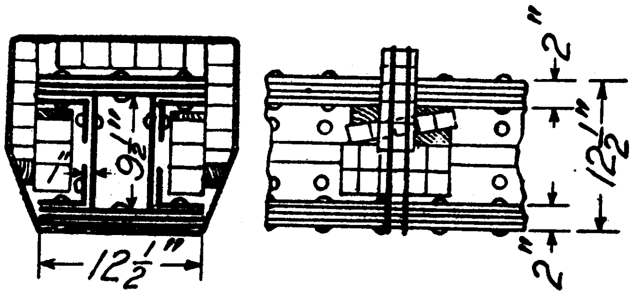
$$30'' \times \tfrac{1}{2}'' = 15.0 \text{ sq.in}$$
$$8'' \times 2 \times 1\tfrac{5}{8}'' = 26.0 \text{ sq.in.}$$
$$4'' \times 2 \times 1\tfrac{5}{8}'' = \underline{13.0} \text{ sq.in.}$$
$$54.0$$

$$\text{Charge} = \tfrac{3}{4} \times 54.0 \text{ sq.in.} = 40.5$$

Charge 41 Blocks of T.N.T.

Fig. 235

A very strong Box Girder



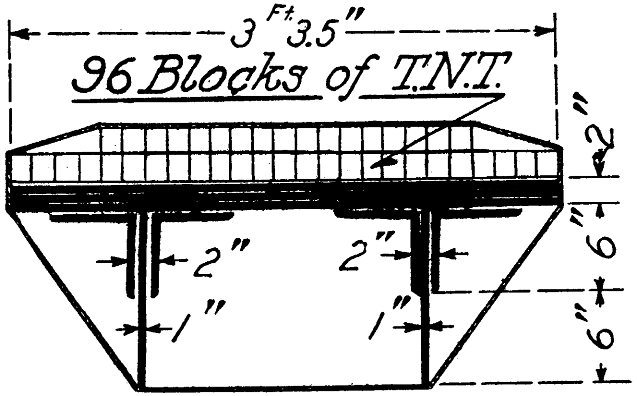
$$\left(12\tfrac{1}{2}'' \times 1\tfrac{1}{2}''\right) \times 2 = 37.5 \text{ sq.in.}$$
$$\left(9\tfrac{1}{2}'' \times \tfrac{1}{2}''\right) \times 2 = 9.5 \text{ sq.in.}$$
$$\left(6'' \times \tfrac{1}{2}''\right) \times 4 = \underline{12.0} \text{ sq.in.}$$
$$59.0 \text{ sq.in.}$$

$$\text{Charge} = \tfrac{3}{4} \times 59.0 \text{ sq.in.} = 44.25$$

Charge 45 Blocks of T.N.T.

Fig. 236

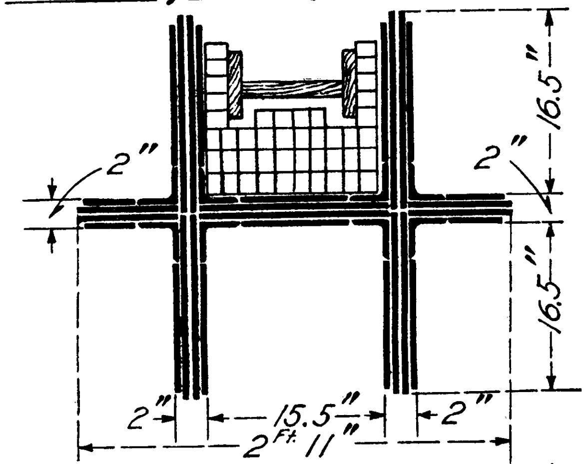
Upper Chord of a large Bridge



$$39.5'' \times 2'' = 79.0 \text{ sq. in.}$$
$$(12'' \times \tfrac{1}{2}'') \times 4 = 24.0 \text{ sq. in.}$$
$$(12'' \times 1'') \times 2 = \underline{24.0} \text{ sq. in.}$$
$$127.0 \text{ sq. in}$$
$$\text{Charge} = \tfrac{3}{4} \times 127.0 \text{ sq. in.} = 95.2 \text{ or } 96$$

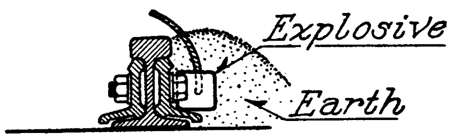
Fig. 237

Chord of a very long Bridge



$$(16.5'' \times 2'') \times 4 = 132.0 \text{ sq. in.}$$
$$15.5'' \times 2'' = 31.0 \text{ sq. in.}$$
$$(7.75'' \times 2'') \times 2 = \underline{31.0} \text{ sq. in}$$
$$194.0 \text{ sq. in.}$$
$$\text{Charge} = \tfrac{3}{4} \times 194.0 \text{ sq. in.} = 146 \text{ Blocks of T.N.T.}$$

Fig. 238



Use of Explosive for cutting R.R. rails

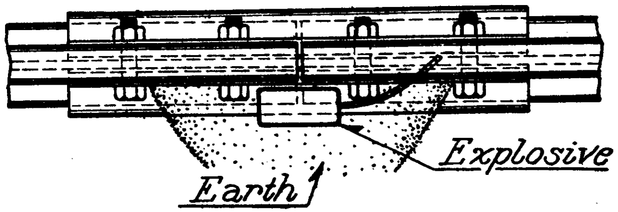


Fig. 239

Use of explosive on switches

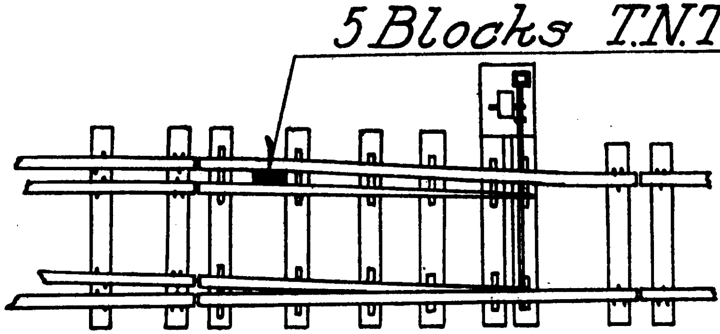


Fig. 240

Use of explosive on frogs

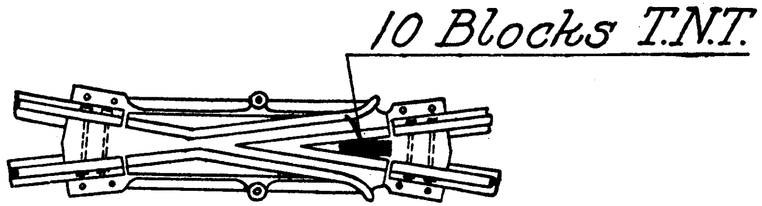


Fig. 241

Use of explosive on crossings

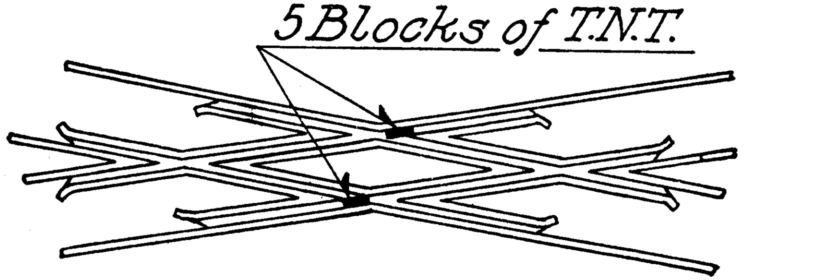
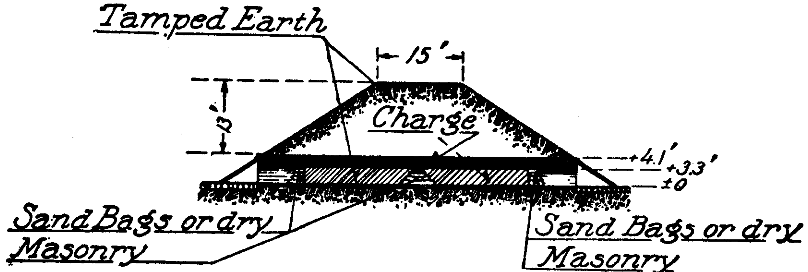


Fig. 242



Demolition of a railroad fill at a culvert.
Charge = 760 Blocks of T.N.T, see Table "D"

In case of a timbered tunnel, the timber bents may be demolished by cutting the vertical posts. The charges should be placed as shown in figure 243. The bents demolished should be located at the point where the heaviest load is carried by the timbering. This point can often be located by observing the effects of the weight in distorting the timber. Generally, the heaviest load is carried at the point where the timber bents are most closely spaced. Figure 243 below shows typical American segmental tunnel timbering such as is used in nearly all timbered tunnels in North America. Several indications of heavy loads above the timbering are noted on the figure.

262. The service of demolition may be concerned with almost any natural or artificial object. The determination of the most effective point of demolition for structures or materials blasted calls for a fairly broad general engineering knowledge. However, such important structures as bridges, railroads, aqueducts, viaducts, roads, retaining walls, and heavy buildings can be readily attacked with explosive by the application of the formula given.

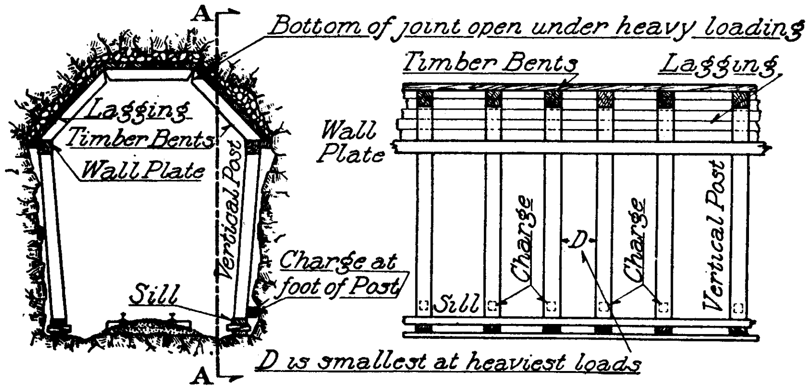
263. **Field guns and howitzers** may be destroyed (*a*) by placing a shell in the breech, closing the breech, and detonating a block of triton, tamped against the fuse of the shell; or (*b*) by filling the bore, just forward of the first hoop, with from two to five blocks of triton, tamping it firmly at both ends with sod, closing the breech, and detonating the triton; or (*c*) by placing from 12 to 15 blocks on the outside of the tube just forward of the first hoop. Methods (*a*) and (*b*) throw fragments with great violence and are as dangerous as they are reliable. Method (*c*) is the safest for the firing detachment, but the least reliable. A gun may be disabled temporarily by opening the breech, setting a block of triton against the hinge, partially closing the breech, and detonating the explosive.

A vehicle of any kind is disabled by detonating three triton blocks against one of the axles.

264. **Ice** can be removed by blasting if there is a current to carry the loosened blocks away and clear water near to receive them. The connection with the shore should first be broken. Small charges rather close together are necessary; on the surface covered with earth if the ice is thin, in drill holes if very thick. This work will be progressive, and charges, distances, etc., can be determined by trial better than from any rule.

266. By following the **instructions** above there will be no difficulty in destroying buildings, bridges, railroads, artillery, machinery, military obstacles, etc., provided an adequate supply of explosive is available. Since triton can be transported with perfect safety under most adverse conditions, there should be no difficulty in the replenishment of supplies. Figure 244 illustrates in a comprehensive way the pioneer work and possible demolitions for an assumed locality.

Fig. 243



Cross Section Longitudinal Section AA

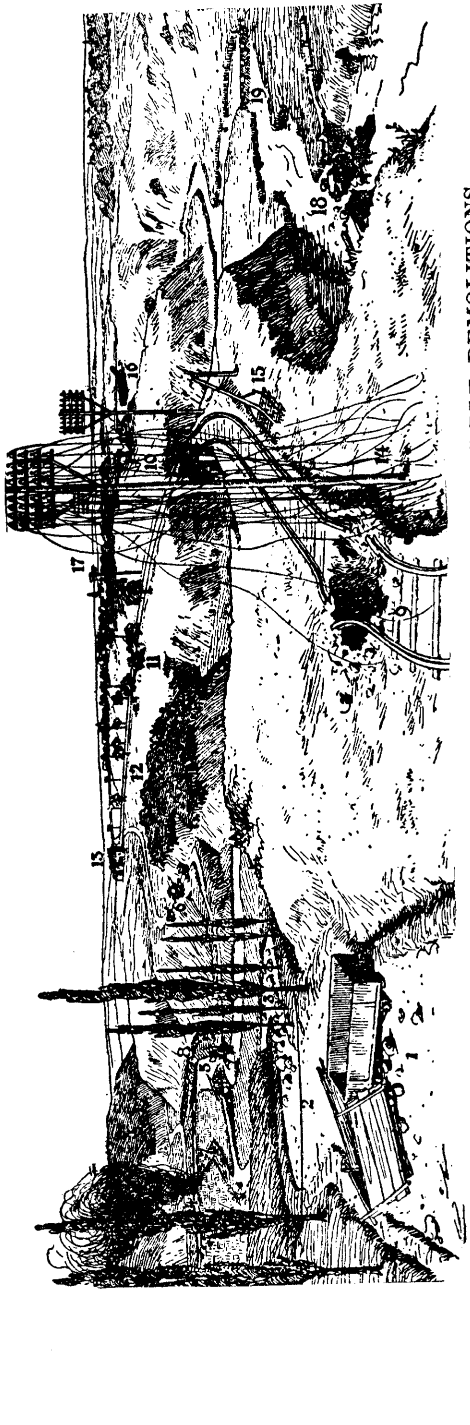


FIG. 244.—EXAMPLES OF PIONEER WORK AND POSSIBLE DEMOLITIONS.

Key: 1. Wagon Barricade. 2. Wire Cable Across Road. 3. Large Stones in Road. 4. Burning Wooden Bridge. 5. Demolished Iron Bridge. 6. Barricade of Trees. 7. Inundated Road. 8. Torn-up Road. 9. Rails Cut With Explosive. 10. Demolished Stone Bridge. 11. Trees Felled Across Road. 12. Concealed Injury to Rail. 13. Destroyed Railroad Station. 14. Telegraph and Telephone Wires Cut Down. 15. Telegraph Poles Cut Down. 16. Destroyed Cable Conduit. 17. Concealed Ground in Telegraph Wires. 18. Destroyed Stone Bridge. 19. Steel Net to Catch Floating Mines.

grenades and bombs

156. **Grenades and bombs.**—These are containers filled with high explosive designed to be thrown by hand, hurled by a sling, fired as a rocket or from specially constructed bomb guns, or dropped from aerial craft. They burst either by time or percussion fuses, may be improvised in a variety of forms, and are useful in a close attack or defense. As in the case of other high-explosive projectiles, their material effect is very local, although demoralizing to men's nerves. Incendiary grenades have been used containing the ingredients necessary for making the welding compound known as thermit and, therefore, throwing molten metal about upon bursting. The type of grenade causing the most havoc is that known as an "aerial mine" or "winged torpedo" (figs. 131 and 132). Aerial mines are usually much heavier than torpedoes, often weighing 200 pounds, but the latter obtains greater accuracy and range, carrying a 40-pound projectile about 500 yards. Both may be used to beat down effectively the enemy's defenses, destroying his sandbags and revetments, and cutting away wire entanglements and other obstacles.

157. **Hand grenades.**—In addition to the types furnished by the supply departments, many good hand granades can be improvised with material at hand. Care must be exercised to obtain the correct length of fuse. One inch usually burns for one and one-fourth seconds, but each lot of fuse should be tested. Troops should be practiced in the manufacture and use of grenades such as these. Figure 133 shows a bomb constructed on a piece of wood, thus giving a good throwing handle. Figure 134 illustrates one made from a tin can; figure 134a, one made of nails.

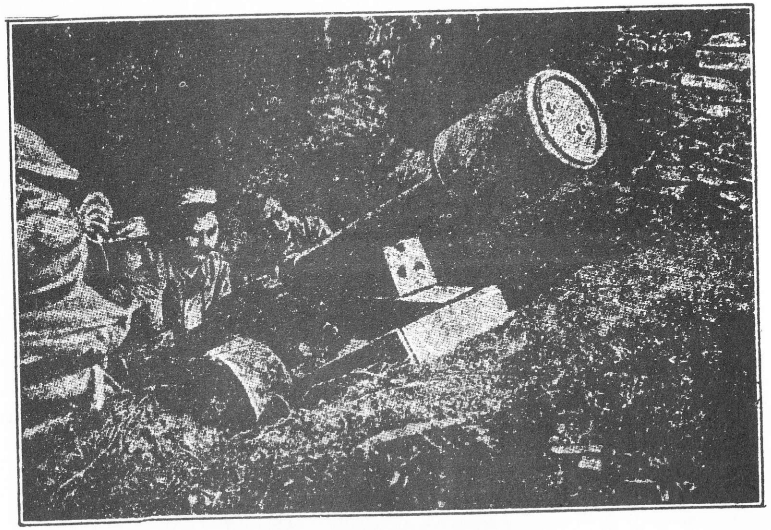


Fig. 131

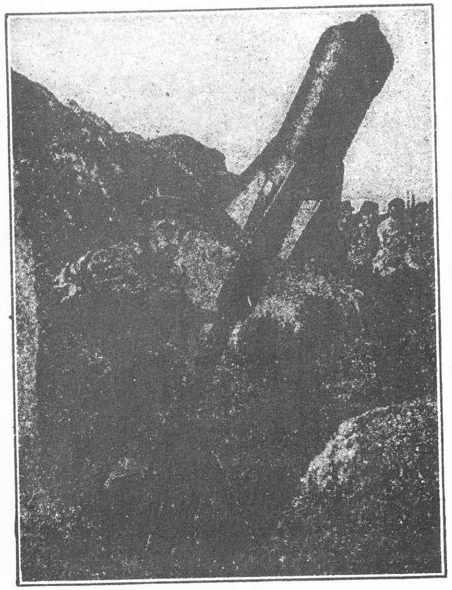


Fig. 132

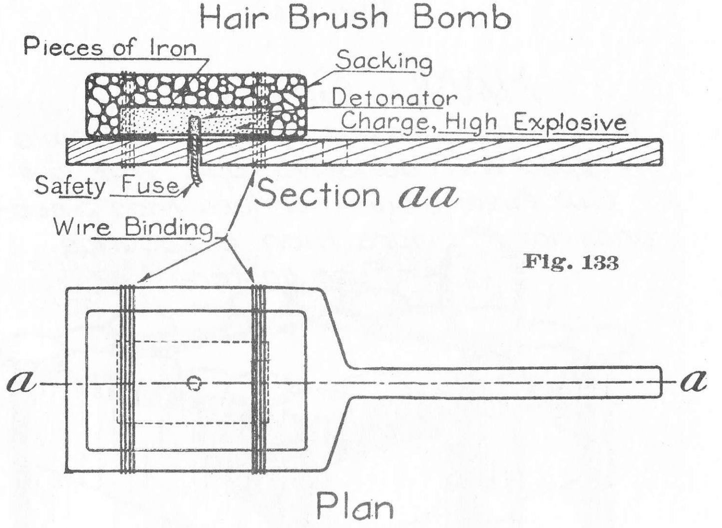


Fig. 133

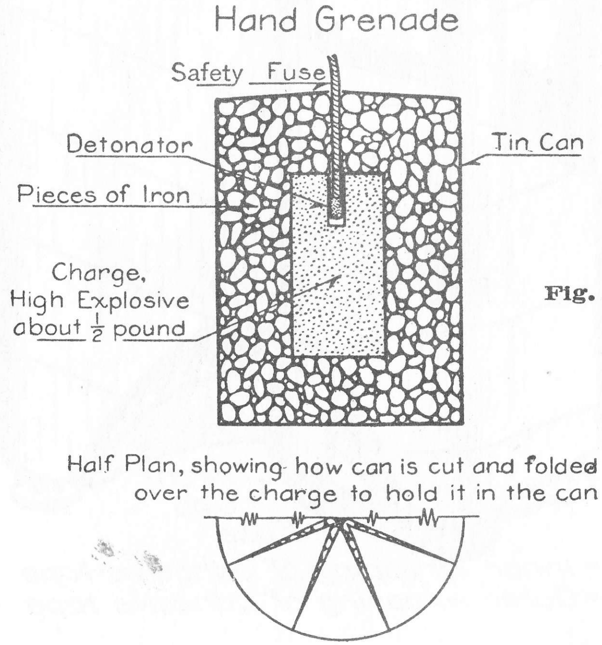


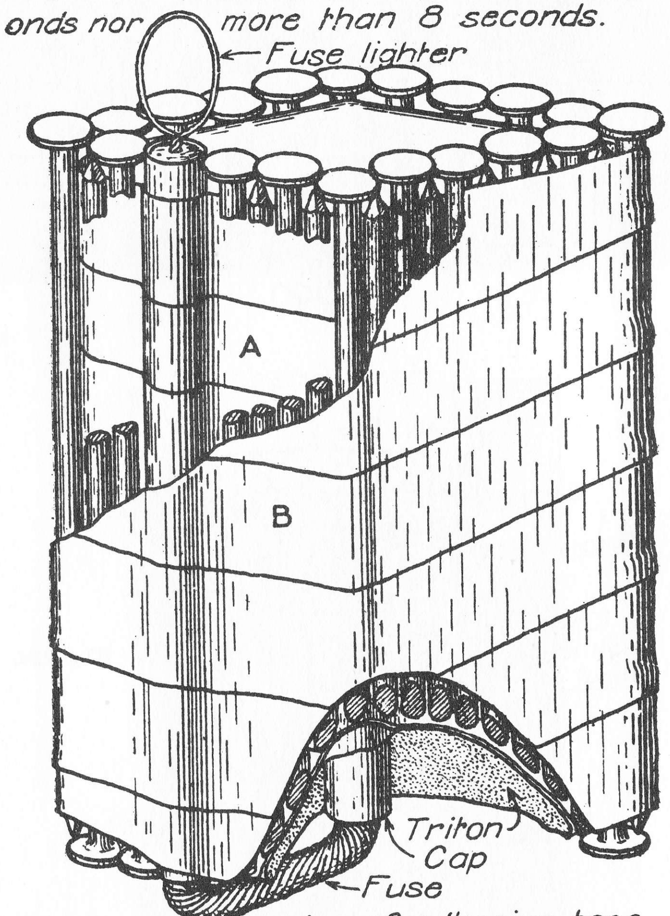
Fig. 134

Fig. 134 a

HAND GRENADE

Triton block and one layer of 16d nails wrapped with adhesive tape. Wgt. $1\frac{1}{4}$ #

Cut fuse to burn not less than 5 seconds nor more than 8 seconds.



A = Inner wrapping of adhesive tape
B = Outer wrapping of adhesive tape